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UNITED STATES ATOMIC ENERGY COMMISSION

NEW YORK OPERATIONS OFFICE

RADIOACTIVE DEBRIS FROM OPERATION CASTLE

AERIAL SURVEY OF OPEN SEA FOLLOWING YANKEE-NECTAR

December 20, 1954

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Effects of Atomic Weapons

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RADIOACTIVE DEBRIS FROM OPERATION CASTLE
AERIAL SURVEY OF OPEN SEA FOLLOWING YANKEE-NECTAR

by

Harris D. LeVine
Robert T. Graveson

UNITED STATES ATOMIC ENERGY COMMISSION
New York Operations Office
Health and Safety Laboratory
Instruments Branch

December 20, 1954

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Effects of Atomic Weapons

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FOREWARD

In order to provide much needed information on the magnitude of fall-out from megaton bombs detonated close to the earth's surface, the Health and Safety Laboratory, during the period immediately preceding CASTLE was engaged in developing a method for documenting fallout on the open sea.

Pre-CASTLE studies consisted in attempts to lay oil blankets several hundred feet in diameter which would float in the region of anticipated fallout, would catch the fallout particles and, retain them long enough for radiation measurements to be made from aircraft. These studies failed and we were unable to propose what we considered to be a satisfactory method for attacking this problem.

The heavy fallout which occurred in the Marshalls after the March 1st event brought an even higher order of importance to the requirement for fallout information. Dr. John C. Bugher requested the Health and Safety Laboratory to restudy the problem and to mount an all out effort to obtain some data from the remaining CASTLE detonations.

A plan was conceived involving the laying of several hundred rafts by low flying aircraft in a 360° pattern. The rafts were equipped with radio-sondes which would assist search aircraft to locate them for radiation measurements approximately 24 hours post shot. This plan which is described in the Appendix, Section VII of this report failed despite the best efforts of the Laboratory staff and the superb cooperation provided by various Commands of the Department of Defense.

A primary deterent to the success of the raft program was the fact that a large area of the Pacific was found to be radioactive. Presumably this is due to suspended or dissolved radioactivity. The importance of this observation was immediately realized, and the Commander, Joint Task Force #7 offered every cooperation to enable the Health and Safety Laboratory to obtain maximum data. Surface vessels were ordered into the fall-out region and they obtained valuable water samples which subsequently lent meaning to the radiation measurements being made aloft.

The mission was successful and this report provides a quantitative description of the fallout from NECTAR and YANKEE.

Dr. Bugher's support of this mission was an essential ingredient to its success. Unfortunately, it is not possible to list all the individuals in the AEC, Joint Task Force #7 and other Commands of the Department of Defense who provided support to this program. Its magnitude will be appreciated by the fact that within ten days after the need for the survey was determined, two C-97s loaded with personnel, equipment and supplies were already on their way to Eniwetok. The procurement of the materials and equipment was a major undertaking and fabrication of these supplies

into the rafts and transmitters that were ultimately dropped into the Pacific was a task which could not have been accomplished without the ingenuity and drive of Mr. Harris D. LeVine and Mr. Robert T. Graveson and others of this Laboratory's Instruments Branch. As mentioned previously Major General Percy Clarkson provided the wholehearted support of Joint Task Force #7 and we are particularly indebted to Lt. Col. Edward Hubbard, members of the staff of CTG 7.2, the officers and men of VP 29, and Dr. T. R. Folsom of Scripps Institute of Oceanography.

Merril Eisenbud, Manager
New York Operations Office

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ABSTRACT

A series of measurements were taken to evaluate the radioactivity in sea water which resulted from bomb debris during the Castle series. The aerial data is correlated with sea water surface and depth activity data to provide an estimate of deposited activity in the measured areas. The technique permits delineation of radioactive areas, will allow early information on direction of heavy fallout paths and will allow more certainty in placement of vessels outside of, or where required, within contaminated sea water areas. This technique also will be useful for civilian defense mapping of contaminated areas on land.

[redacted]

RADIOACTIVE DEBRIS FROM OPERATION CASTLE
AERIAL SURVEY OF OPEN SEA FOLLOWING YANKEE-NECTAR

INTRODUCTION

The incident of heavy fallout on nearby islands as a result of the Bravo detonation made it apparent that much more information was necessary on the behaviour and character of fallout nuclear weapon debris which was airborne and later deposited after carriage over a distance by the wind. As a contribution to the information required, the Health and Safety Laboratory was requested to set up a raft program (1) in order to determine the extent of fallout on rafts placed up to 150 miles from the shot site. Although the results of the raft program were not significant, the aircraft observers reported that marked changes of activity could be read on their instrument when flying over open water. While no valid sea water activity measurements were made on D+1 of YANKEE, it was evident that the readings could not be accounted for by the presence of adjacent clouds of radioactive dust, activity deposited on the rafts, or contamination of the plane in flying through active dust clouds. On D+3 of YANKEE (2) a set of headings, Figure 1, were flown in an attempt to determine the origin of the readings and to evaluate any information that might be forthcoming. On the first heading, which was set at 25 miles from ground zero from YANKEE, it became evident that the sea water itself was radioactive due to shot debris distributed in it, that the area of activity was sharply defined - even three days after the burst - and that the readings at altitudes ranging from 200 to 400 feet were significant. With this encouraging information, a major effort was made to cover the NECTAR shot as fully as possible with the equipment on hand. The authors believe the information contained in this document is useful but it must be realized that this data covers two events only; that the preparation was not as thorough as one might wish; and that the data and conclusions may have to be re-evaluated if an opportunity is presented to more fully study the problem on one or more future tests.

AERIAL FLIGHTS

All aerial flights on these operations were performed in P2V planes with the radiation detector located directly on the interior surface of the skin of the plane to secure minimal absorption of the gamma radiation. The planes were flown in level flight at various altitudes. All data has been corrected back to the sea surface and to 48 hours from each shot time. Figure 2 is the relationship between altitude and attenuation of the reading on the sea

---

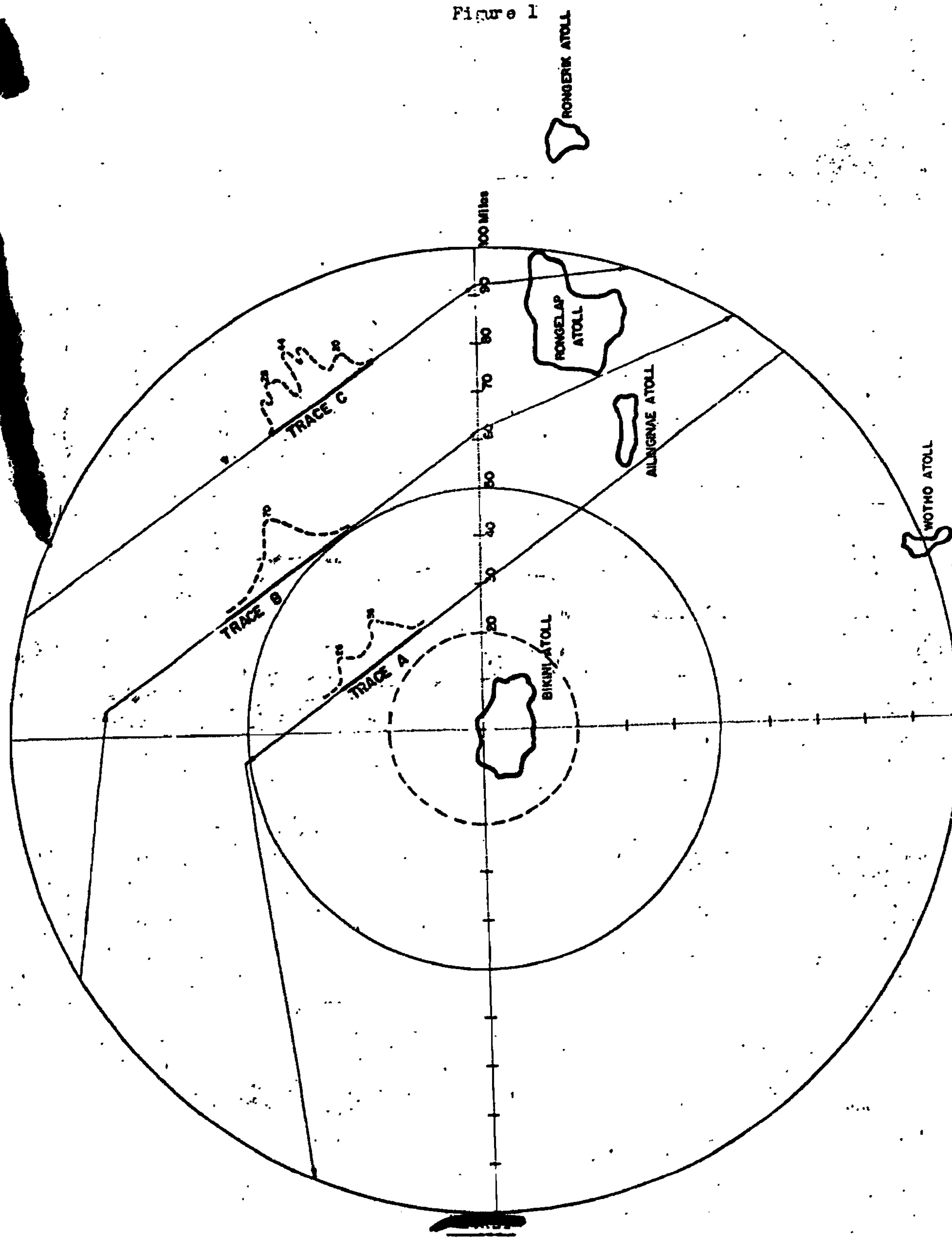
(1) See Appendix, Section VII

(2) A delayed message dated May 1, 1954 was received on Yankee +2 days. Dr. T. R. Folsom, Scripps Institute of Oceanography, Consultant to the 2.5 a program of CTG 7.3, requested that HASL scan the probable zone of fallout with its airborne radiation detectors to give him a general guide in his program of sea water sample collection.

[redacted]

[redacted]

Figure 1



H+73 to H+82
hours

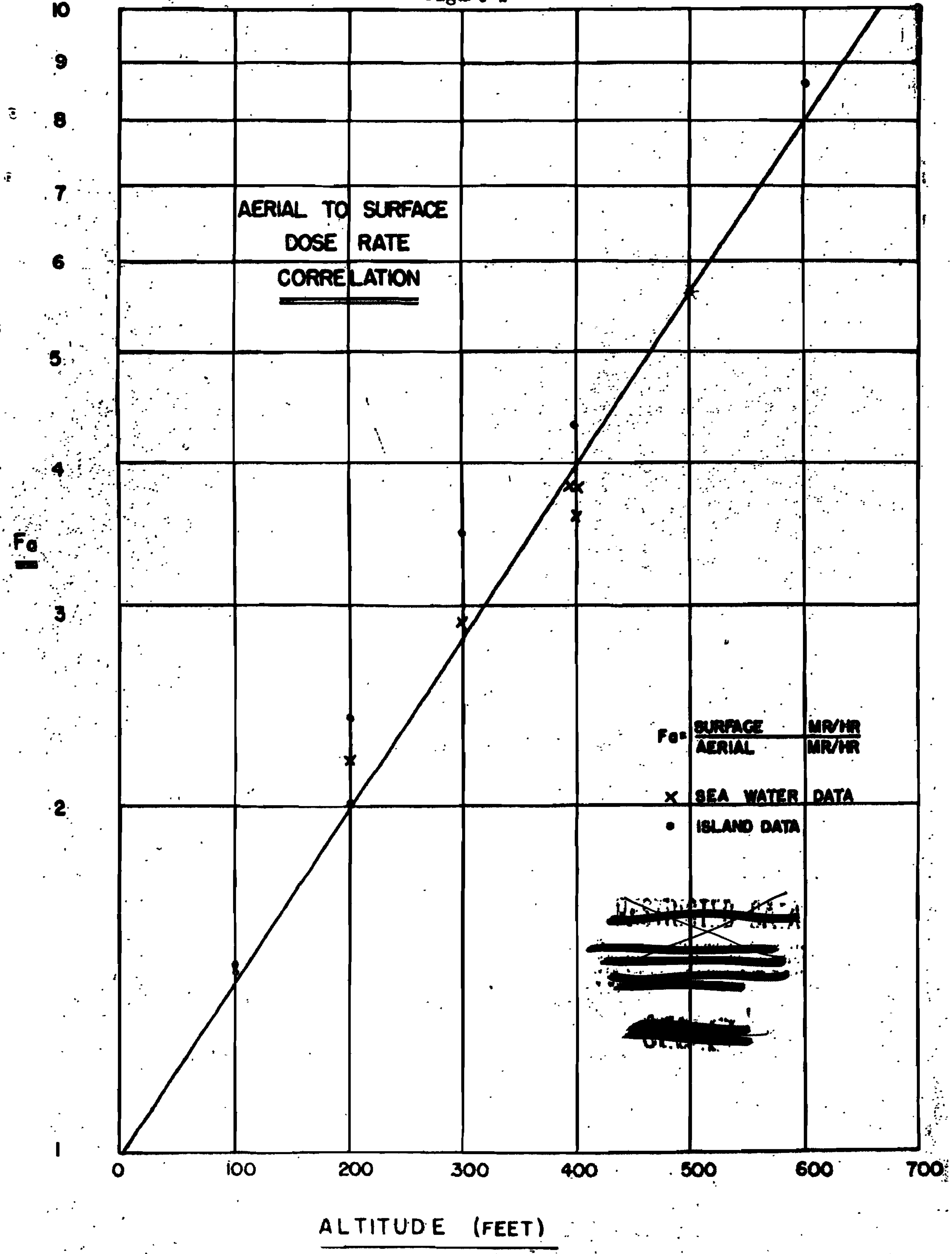
YANKEE - 071925 Z to 080345 Z

NOTE

PROFILE READINGS IN MR/HR EXTRAPOLATED
TO 3 FEET ABOVE SEA.

[redacted]

Figure 2


AERIAL TO SURFACE
DOSE RATE
CORRELATION
Fa
$Fa = \frac{\text{SURFACE MR/HR}}{\text{AERIAL MR/HR}}$
× SEA WATER DATA
• ISLAND DATA
[redacted]
ALTITUDE (FEET)
0
100
200
300
400
500
600
700
1
2
3
4
5
6
7
8
9
10

surface to the reading in an airplane with no added filtration beyond the skin of the plane. This data represents a summarization of information secured on previous HASL operations and is considered to be reliable (3). The corrections depend on altitude and are only as reliable as the barometric type of altimeter would permit. This type of instrument does not allow for complete confidence but was the most reliable apparatus available.

A. Yankee

On D+3 of YANKEE, three headings were flown with two P2V planes as shown in Figure 1. The correction back to H+48 hours (4) has been utilized in evaluating the traces of Figure 3. These traces are copies from recorded data taken on Esterline-Angus recorders which operated in conjunction with the radiation detection instruments. Figure 4, the Summation of Wind Vectors (5), is a plot of the probable position of a particle starting from ground zero from a specific height, at various times after the shot. Comparison of this data with Figure 1 indicates that the fallout pattern is related to the wind trajectories.

B. Nectar

At H+12 hours a single plane was utilized to fly the pattern shown in Figure 5. On D+1 the pattern of Figure 6 was flown by two planes; the data taken on one of the planes was useless because of instrument failure. Here again the summation of wind vectors, Figure 7 - for the NECTAR shot period compares favorably with the information of Figure 6. The zone of flight selected for the H+12 hour run, Figure 5, was determined by a study of these trajectories prior to the flight. The planes used in the NECTAR flights were in C. W. Radio communication with headquarters, and although it was difficult to transmit a large amount of information, nevertheless sufficient data was received to map the direction of the fallout path and amount of activity, while the flights were still in progress. With the general fallout path thus determined, the two ships that were made available for this program were directed into proper position for collection of surface sea water samples and for radiation measurements from the bridge and fantail of each of the ships.

It should be noted that the activity recorded in the western zone of Figure 6 is here attributed to fallout of particles with initial position after the shot, at an altitude less than 20,000 feet. A flight was made on D+2 and the resultant radiation pattern, Figure 8, reveals that the main zone of activity drifted to a new position due to currents and that the portion in the western lobe had

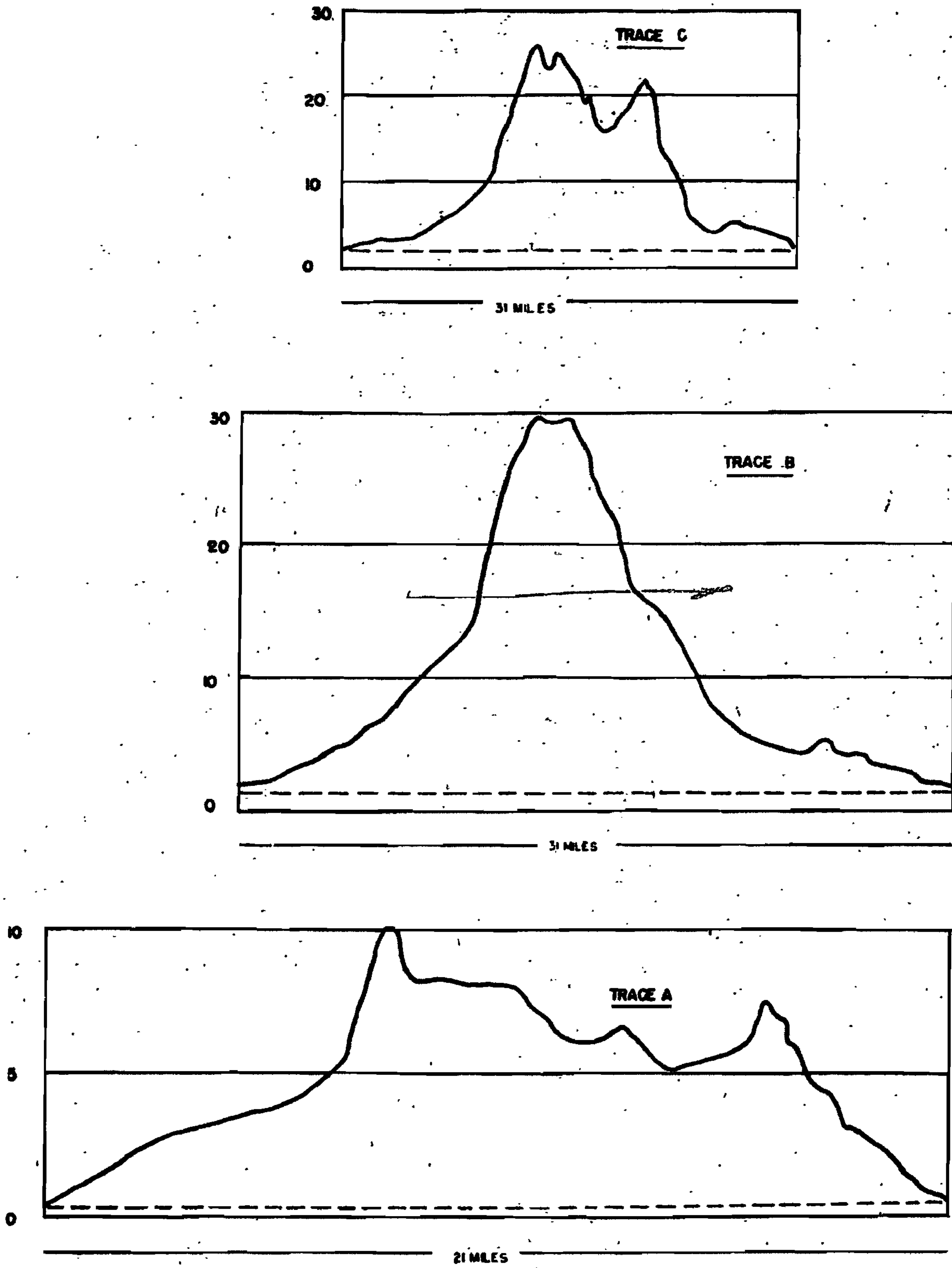
(3) See Appendix, Section I
(4) See Appendix, Section II
(5) See Appendix, Section III

Figure 3

FLIGHT RADIATION TRACES

AFTER YANKEE

H + 73 HRS. TO H + 82 HRS.



NOTE :- SCALES IN MR/HR CORRECTED TO EQUIVALENT SURFACE READINGS AT H+48 HOURS

SOUTH

[redacted]

[redacted]

RESTRICTED DATA [redacted]

[redacted]

Figure 4

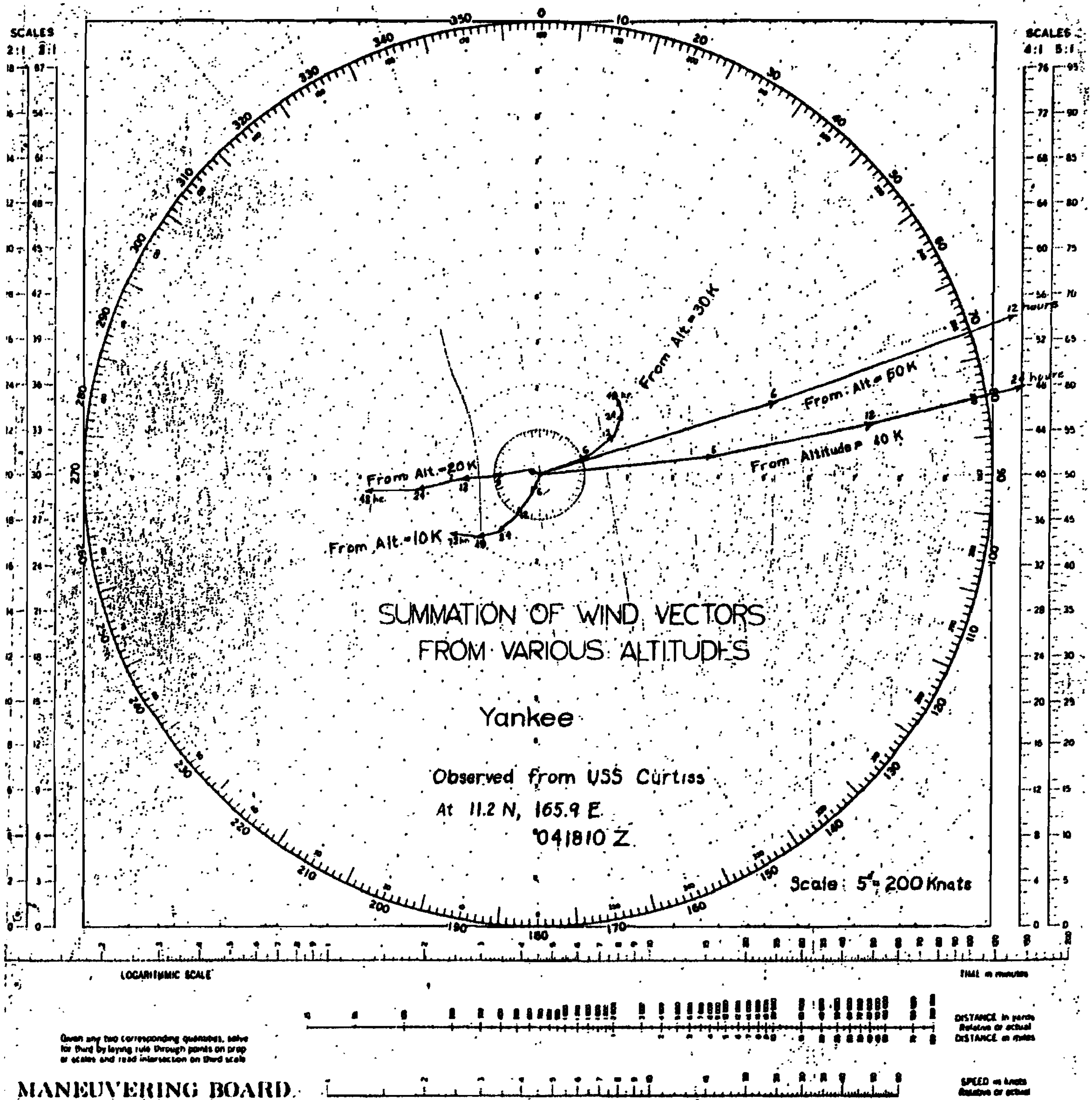


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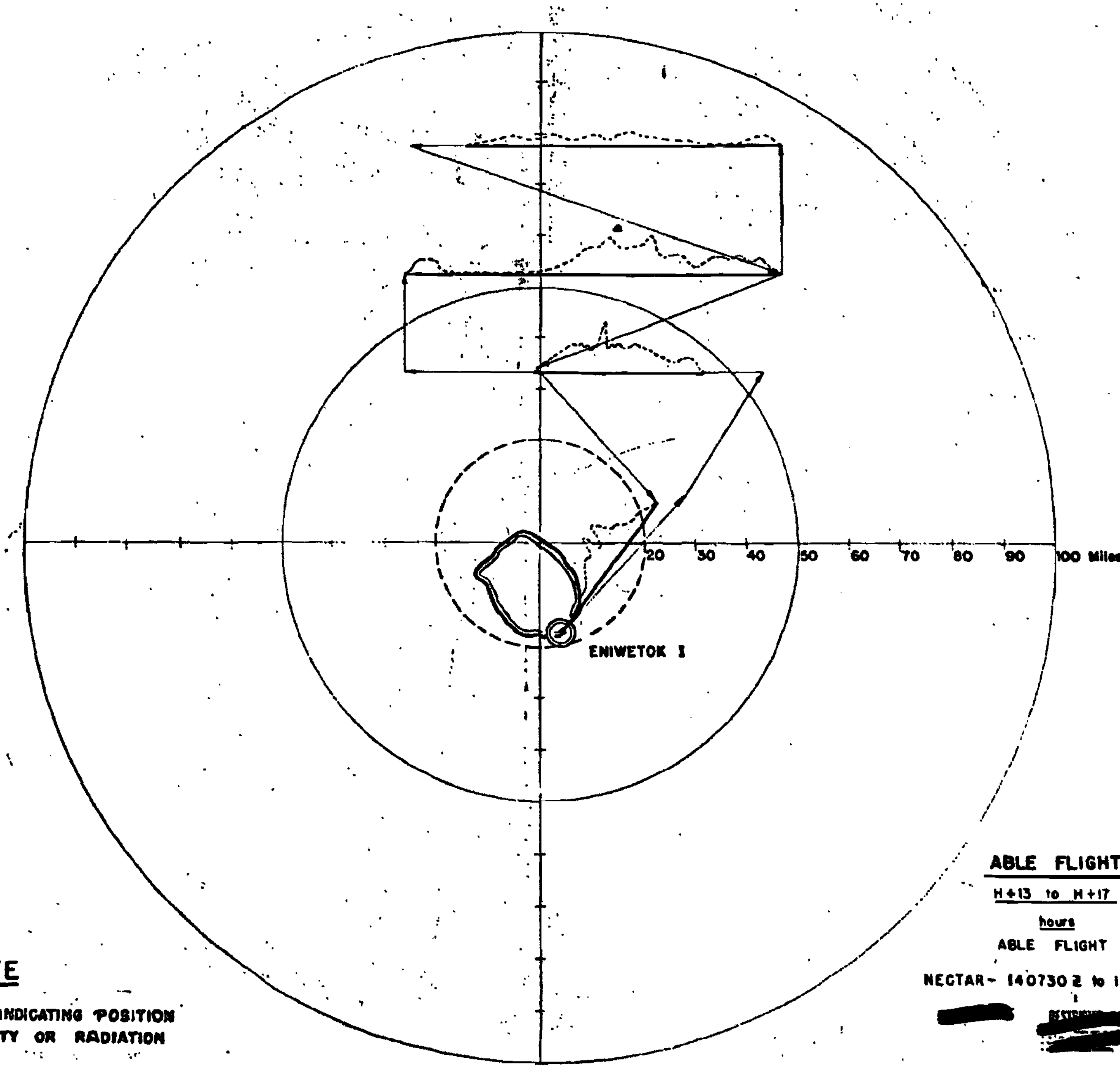
Figure 5



ABLE FLIGHT

H+13 to H+17

hours

ABLE FLIGHT

NECTAR - 140730 Z to 141100 Z

[redacted]

NOTE

PRELIMINARY FLIGHT INDICATING POSITION AND RELATIVE INTENSITY OR RADIATION

[redacted]

Figure 6

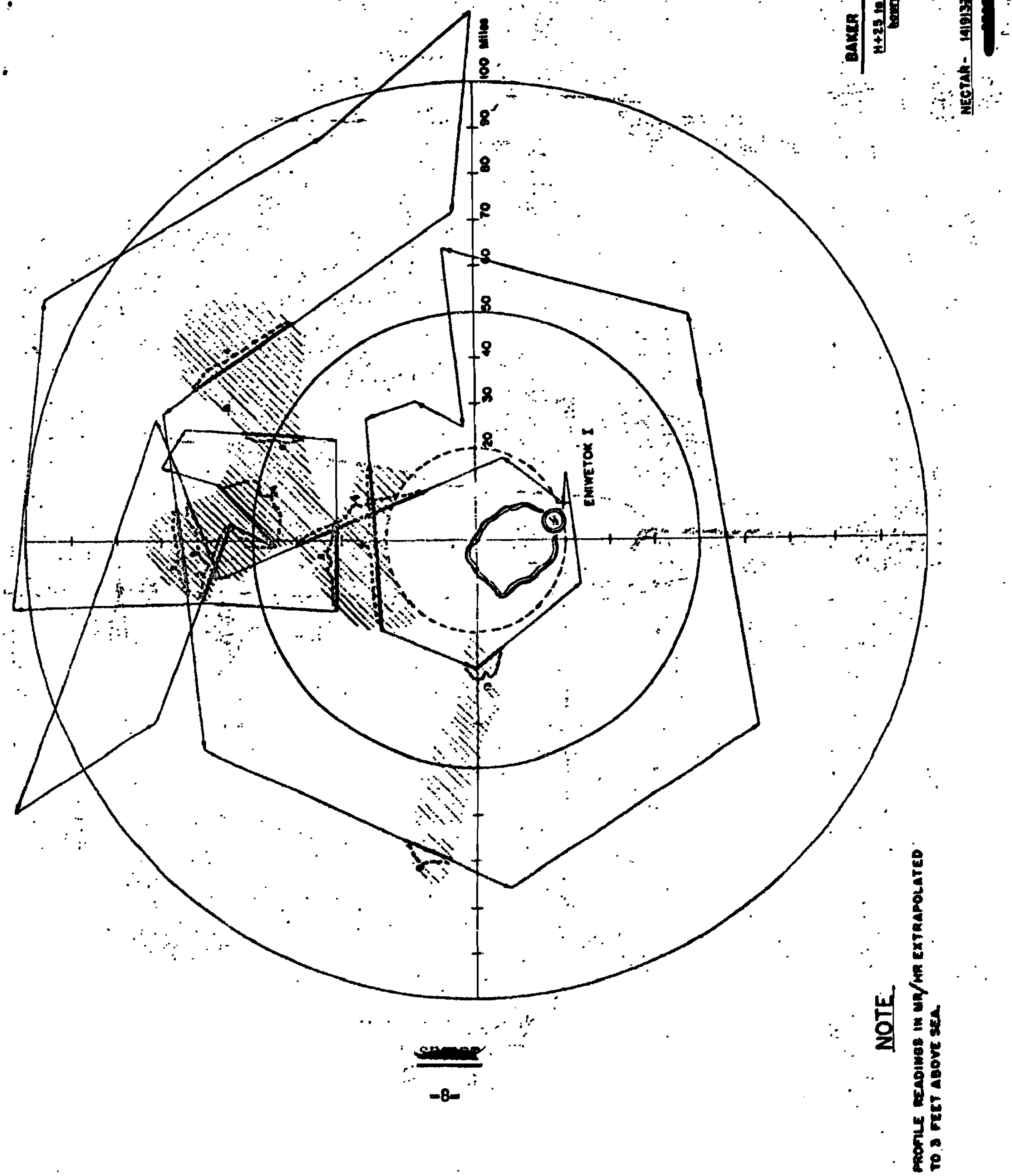


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Figure 7

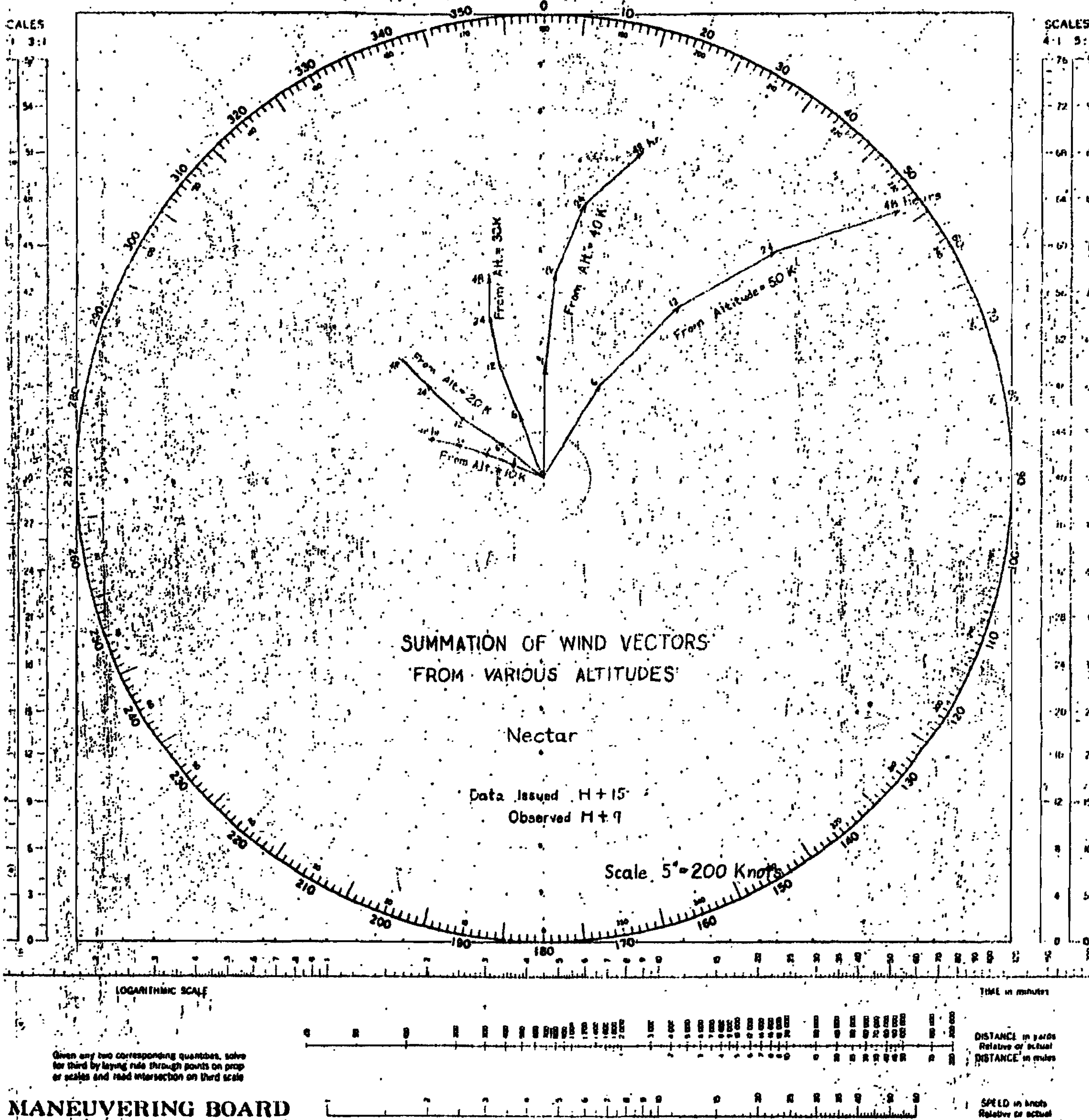

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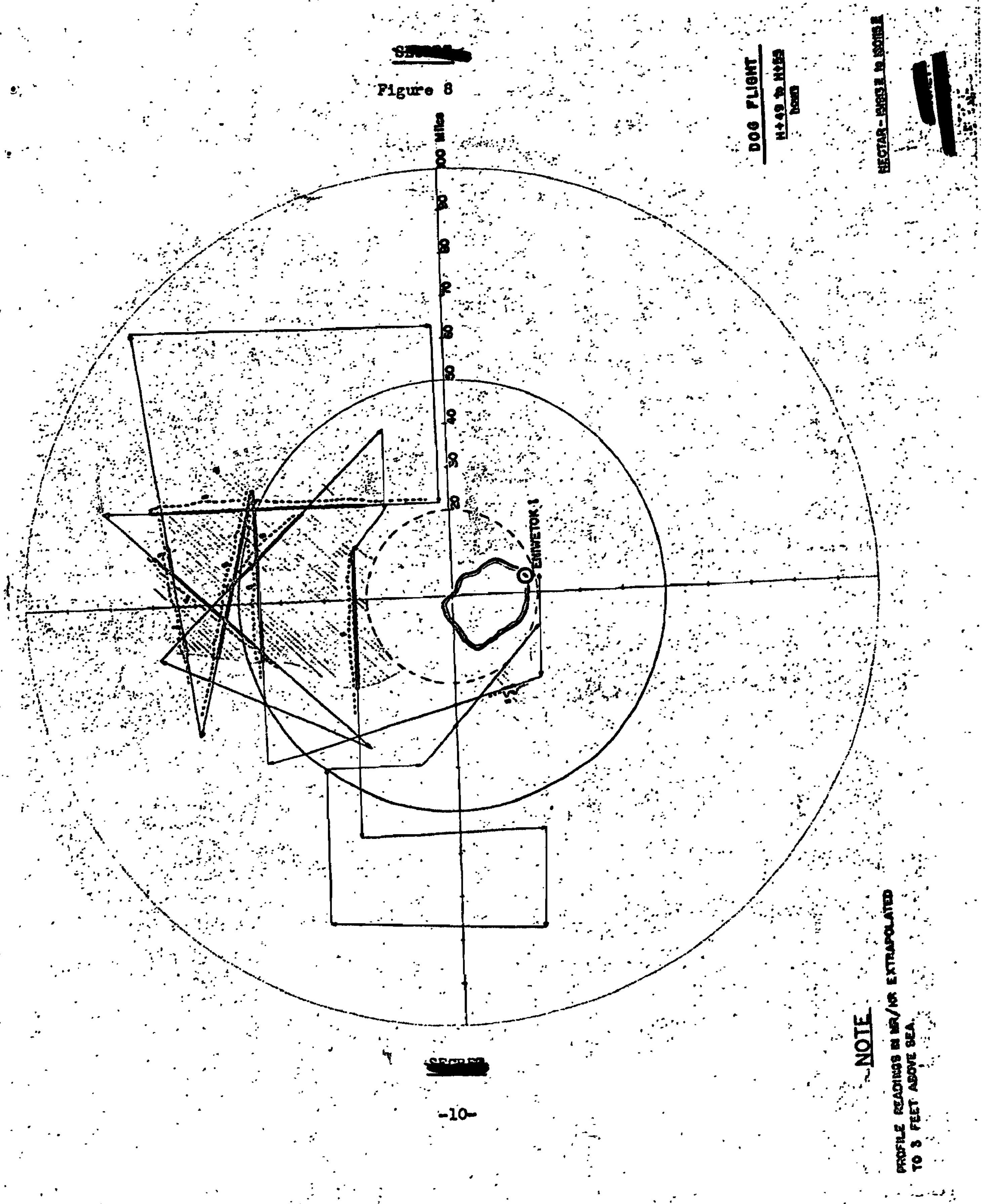
Figure 8



[redacted]

practically disappeared. Since this debris is probably composed of large sized particles, it is reasonable to expect that these would disappear in the depths of the ocean more rapidly than the finer particulate matter which would rise to the higher elevations at the shot and were apparently carried toward the northeast lobe.

SEA WATER SAMPLES AND SEA WATER SURFACE ACTIVITY MEASUREMENTS

A sea going tug traversed the path (6) shown on Figure 9 which corresponds to the path of fallout debris on Figure 1. The drift measured by the tug is reported to be one-half mile per hour. From the same source (6), the depth profile data, Figure 10, reveals that the fallout debris penetrates the sea water, in depth a limited amount each day and seems not to penetrate through the thermocline (7). Little or no lateral diffusion is noted and there is a sharp demarkation of low or no activity beyond the path of fallout debris.

For the NECTAR shot the two sea going tugs followed the patterns of Figure 11 and 12. The voyage of the Sioux was deliberately planned so that it would not generally enter the zone of contamination in order to get a positive affirmation of the lack of sea water activity and radiation levels outside of the area of fallout predicted from the airplane data. Occasionally the Sioux would enter a zone of contamination. The readings increased during the entries and was in agreement with data available.

EVALUATION OF DATA

The series of surface sea water samples from the NECTAR shot were analyzed radiometrically using high geometry geiger counters. This data was compared to radiation readings taken:

1. On the bridge of the ship.
2. Over the fantail of the ships.
3. On occasions when the airplanes flew over the ships and took simultaneous aerial radiation readings as the ship took radiation readings on the bridge and fantail plus surface sea water samples (8). Upon analysis, the data (9) revealed excellent correspondence between surface activity measurements and the quantity of activity to be found in the surface samples taken, Figure 13, when correction of the surface activity and counting data is made

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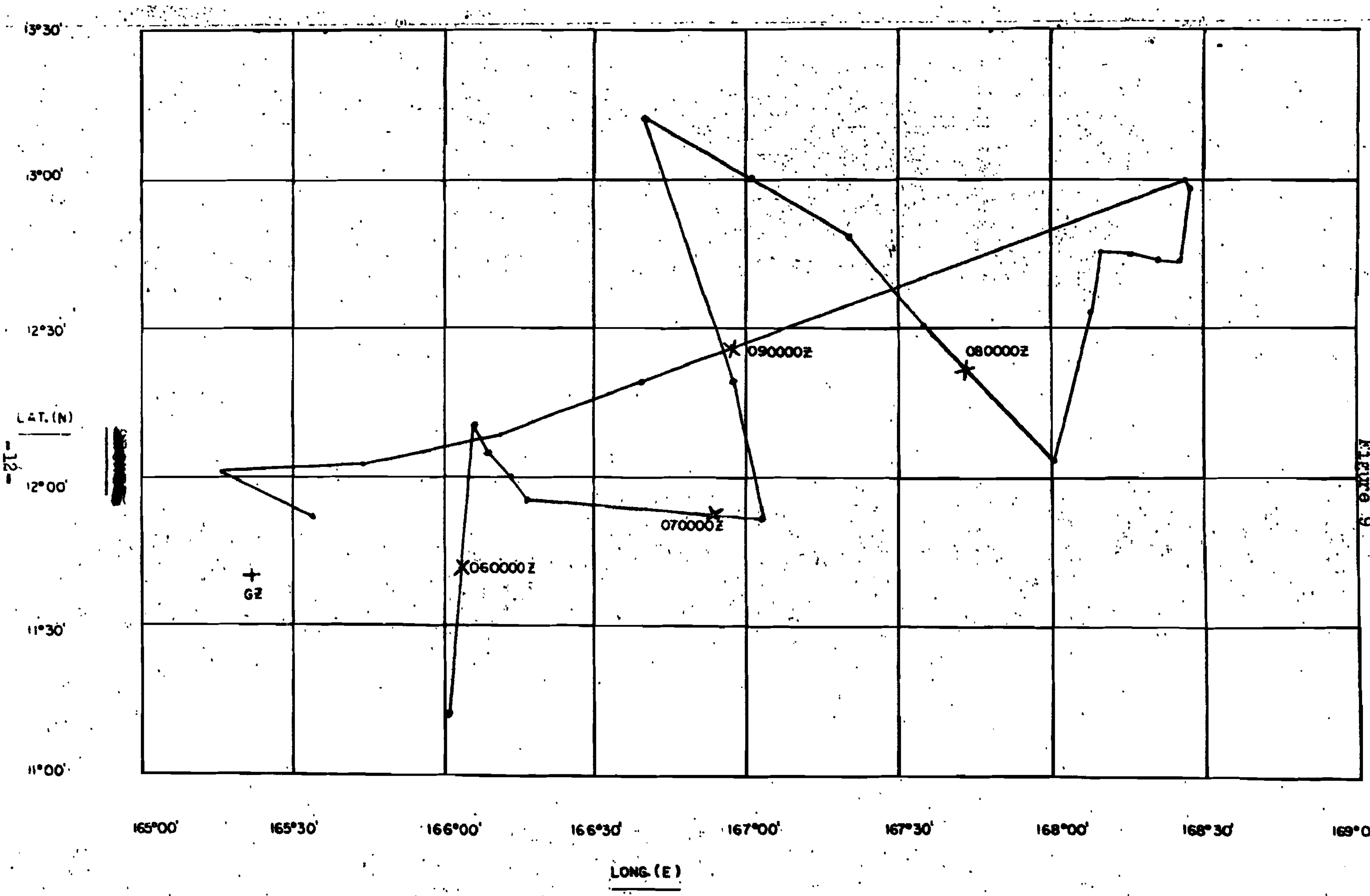
(6) Data submitted by U. S. Naval Radiological Laboratory. Information taken by Scripps Institute of Oceanography on Yankee. See Appendix.
(7) See Appendix, Section IV
(8) See Appendix, Section IV
(9) See Appendix, Section V

Figure 9



[redacted]

SHIP POSITION AFTER YANKEE

NOTE:
DOT INDICATES POSITION WHERE SHIP SAMPLES WERE TAKEN

[redacted]

[redacted]

Figure 10

SURFACE TO TOTAL ACTIVITY CORRELATION

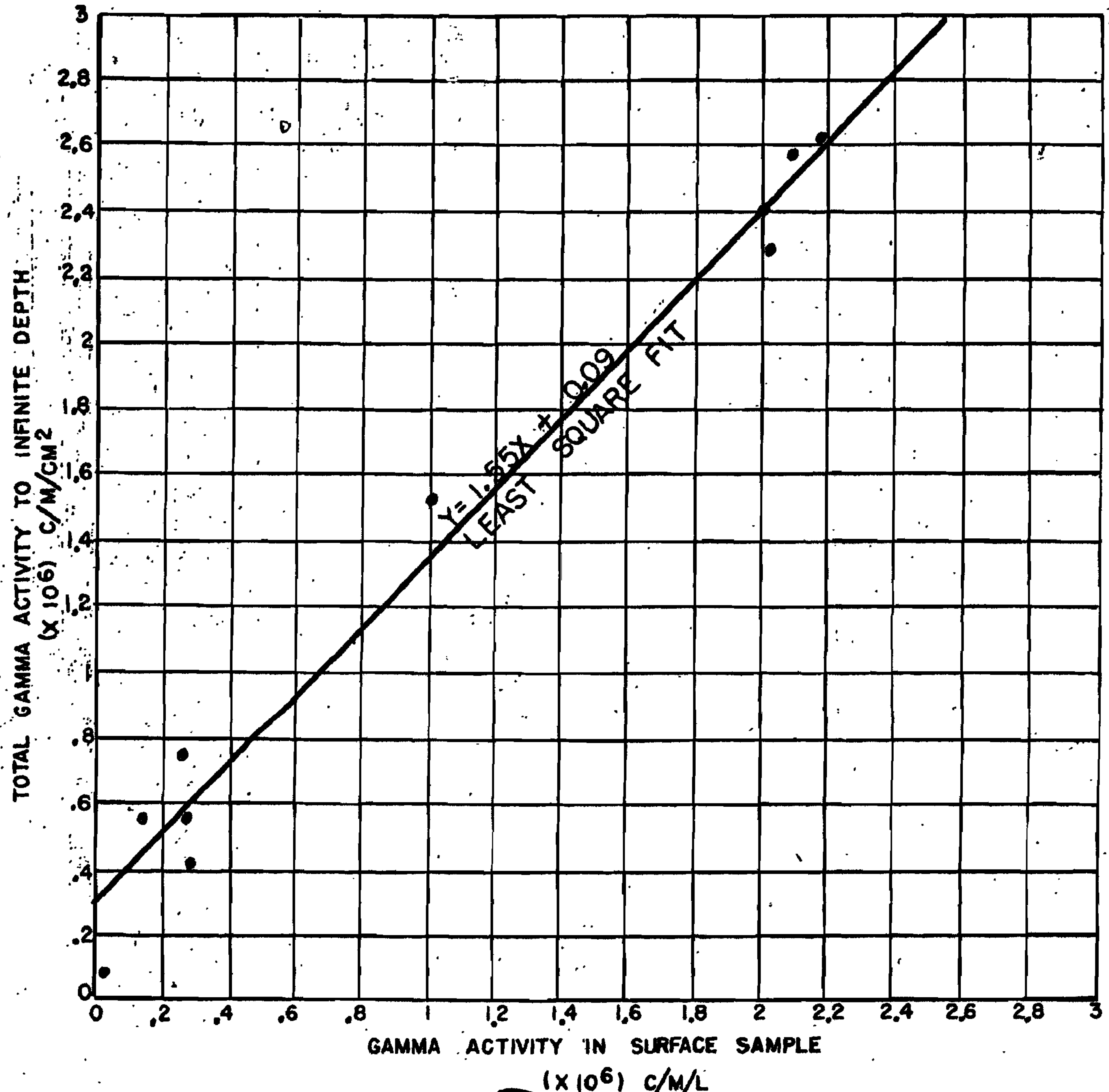


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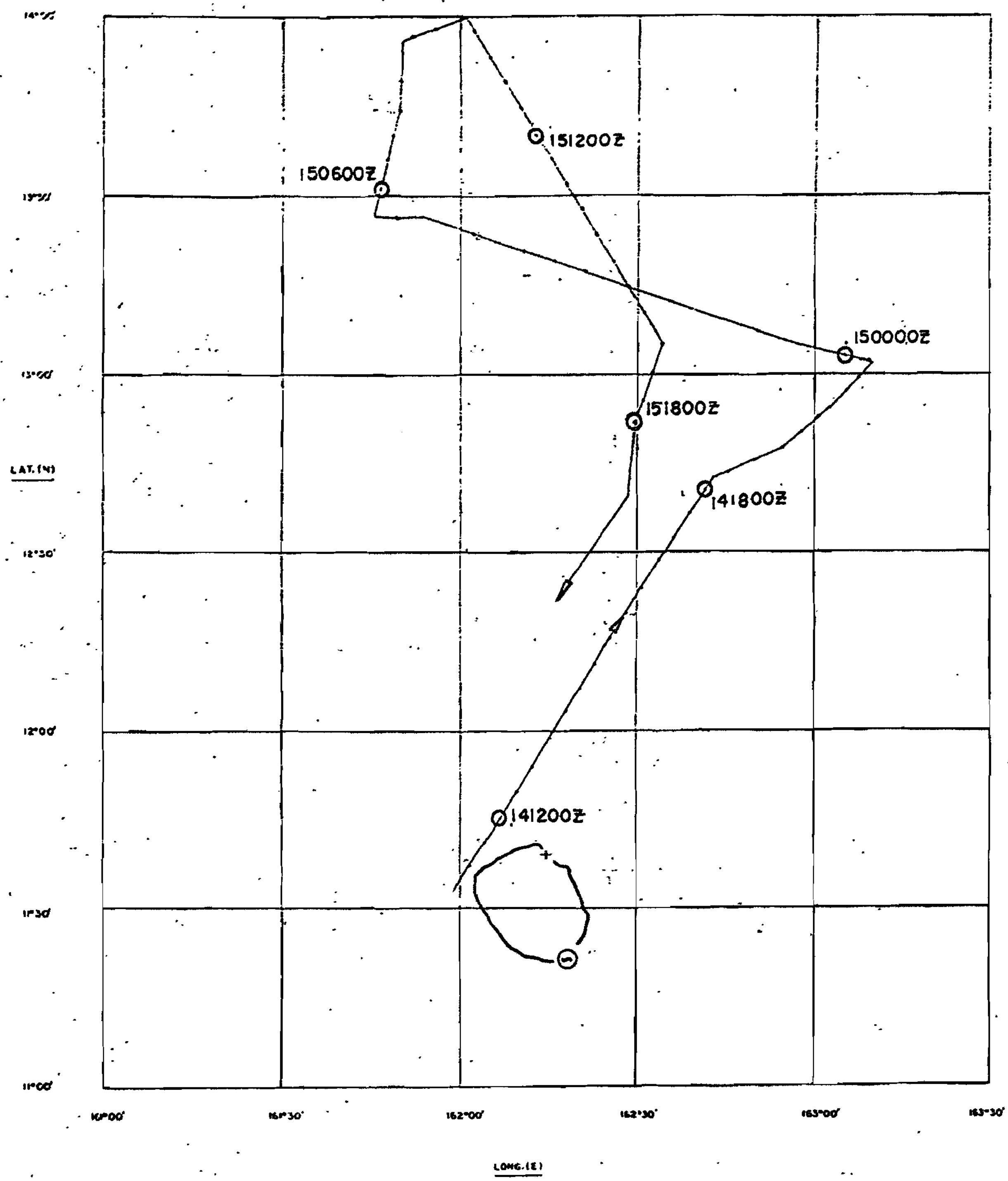
Figure 11



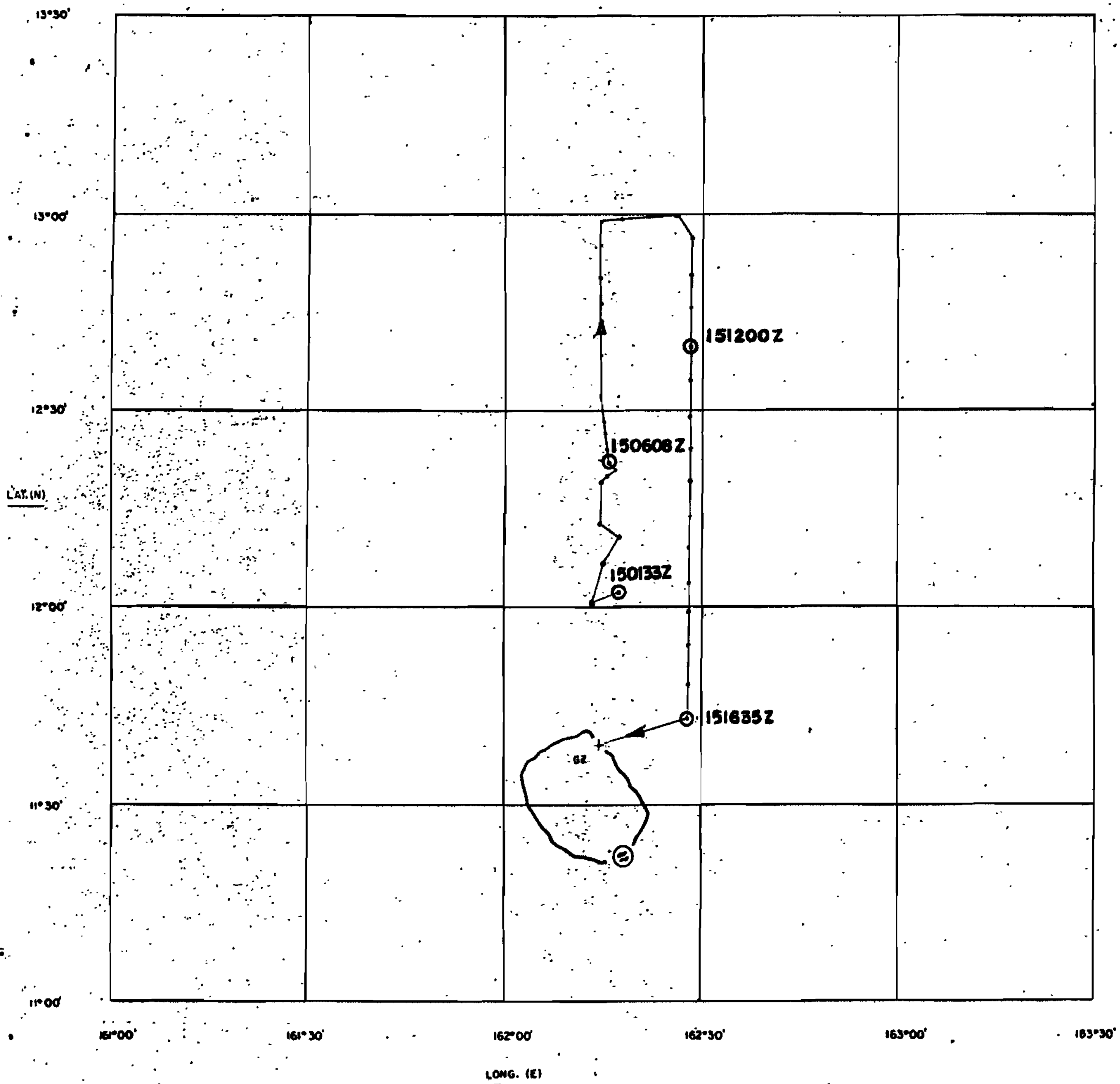
U.S.S. SIOUX POSITION AFTER NECTAR

[redacted]

[redacted]

[redacted]

Figure 12

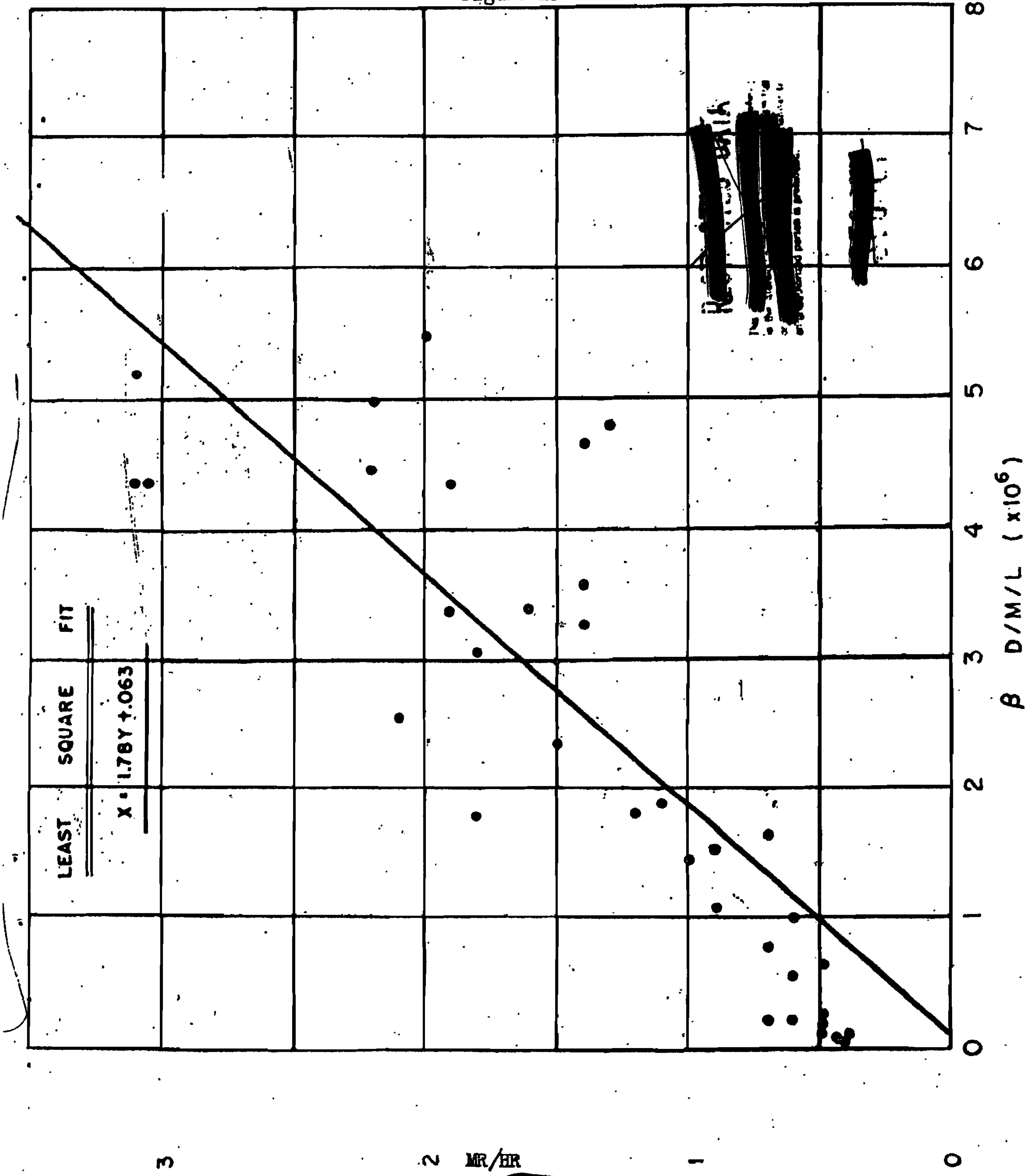


U.S.S. MALOLA POSITION AFTER NECTAR

[redacted]

[redacted]

Figure 13



[redacted]

back to a standard time from zero hour. The relationship of the rate of decay of the activity in the sea water has been computed from decay measurements taken on the sea water samples of NECTAR made both at the Analytical Branch of HASL and NRDL and it can be seen that the exponent is -1.2. Although reports indicated the presence of a large quantity of Neptunium in the activity, because of the short half-life of this element and the length of time which elapsed before the decay data was taken, the contribution of Neptunium to the sea water surface activity could not be evaluated.

With all aerial data of Figure 1 corrected back to a standard time of H+48 hours the radiation data translated down to surface activity provides the information required for isodose curves, Figures 14, 15 and 16.

ISODOSE CURVES

These curves, are attempts to provide an illustration of a possible set of isodoses which might be inferred from the aerial data. There was, of course, insufficient information to provide a reliable isodose plot. Data taken from the recorded traces reveals a rise and fall of radiation levels and these are so distinct that there is no question of the variation of activity deposition in the water. (10)

Table 1

Fallout Calculation*
Yankee

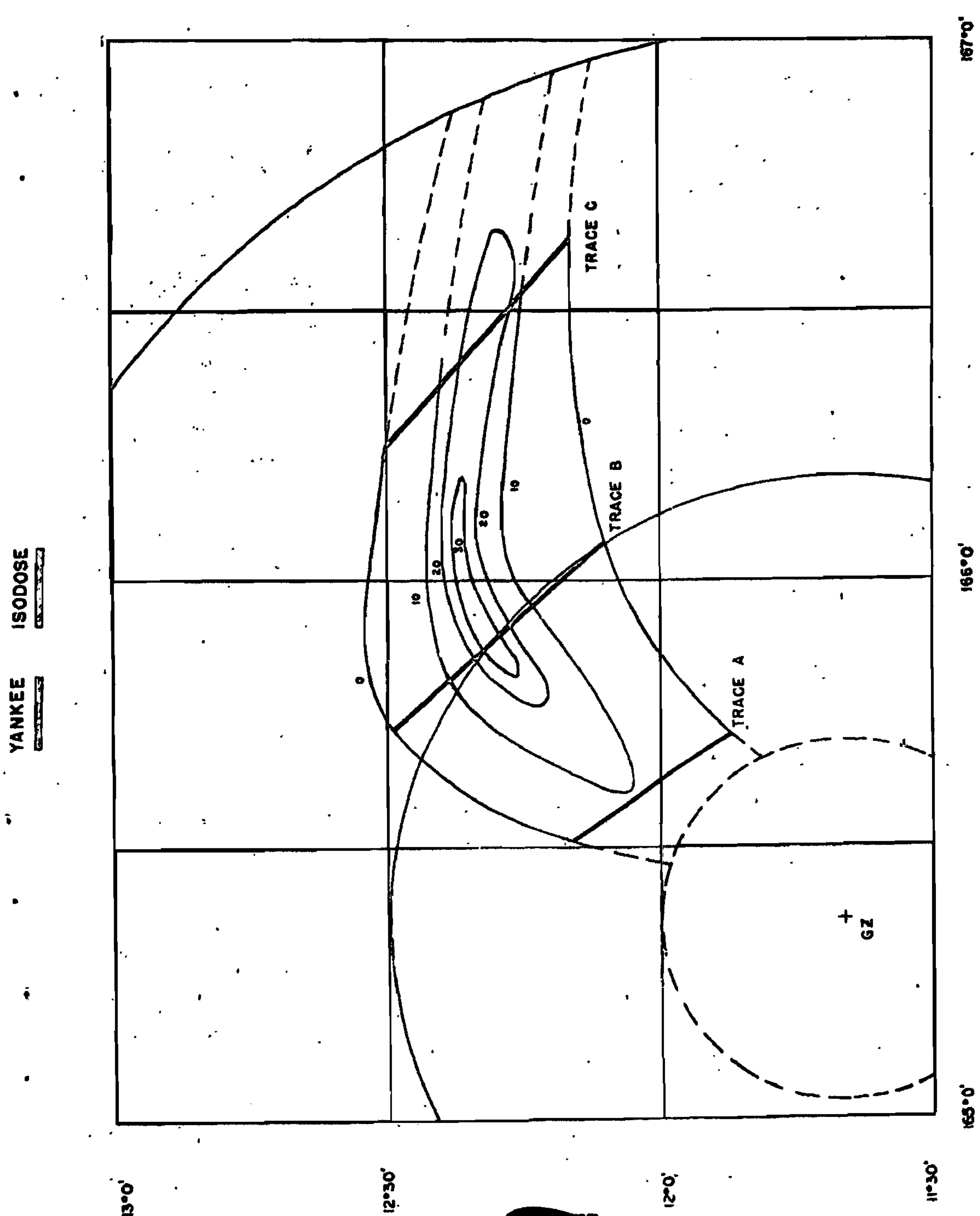
Region	Surface Mean Radiation mr/hr	Curies/sq.cm. ($x10^{-6}$)	Area (mi)^2	Megacuries
0-10	4.9	4.2	1223	172
10-20	14.7	12.2	496	202
20-30	24.1	19.8	196	131
>30	30	24.7	40	33
			1955 sq.mi.	540 megacurie total

* Referred to H+2 days.

(10) See Appendix, Section VI

[redacted]

Figure 14



NOTE:- READINGS IN MR/HR EXTRAPOLATED TO SURFACE AND CORRECTED TO H+2 DAYS

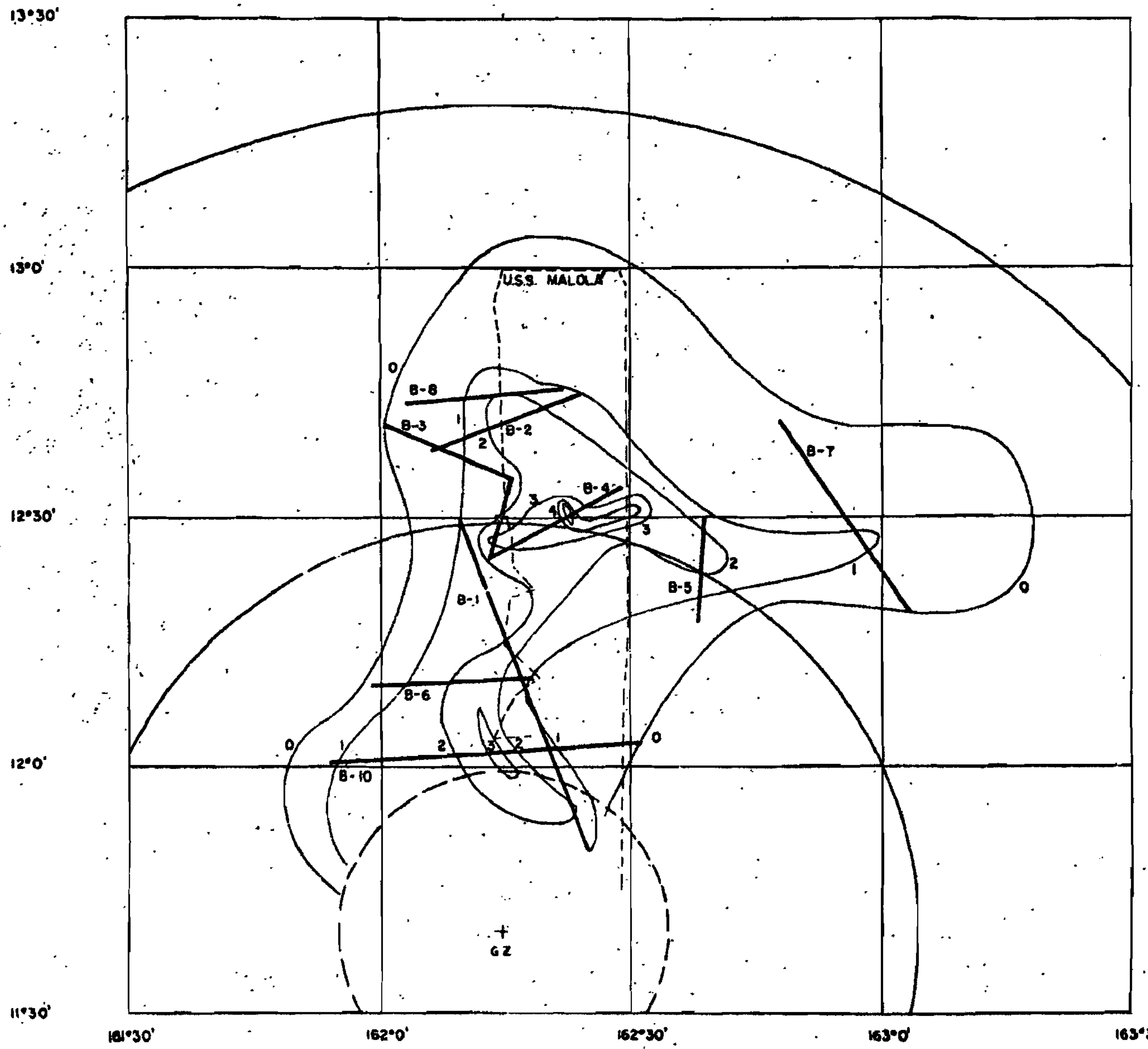
ISODOSE LINES BETWEEN TRACES ARE POSSIBLE CONDITIONS AND SHOULD BE CONSIDERED ILLUSTRATIVE ONLY

[redacted]

[redacted]

Figure 15

NECTAR ISODOSE



NOTE:- READINGS IN MR/HR EXTRAPOLATED TO SURFACE AND CORRECTED TO H+2 DAYS

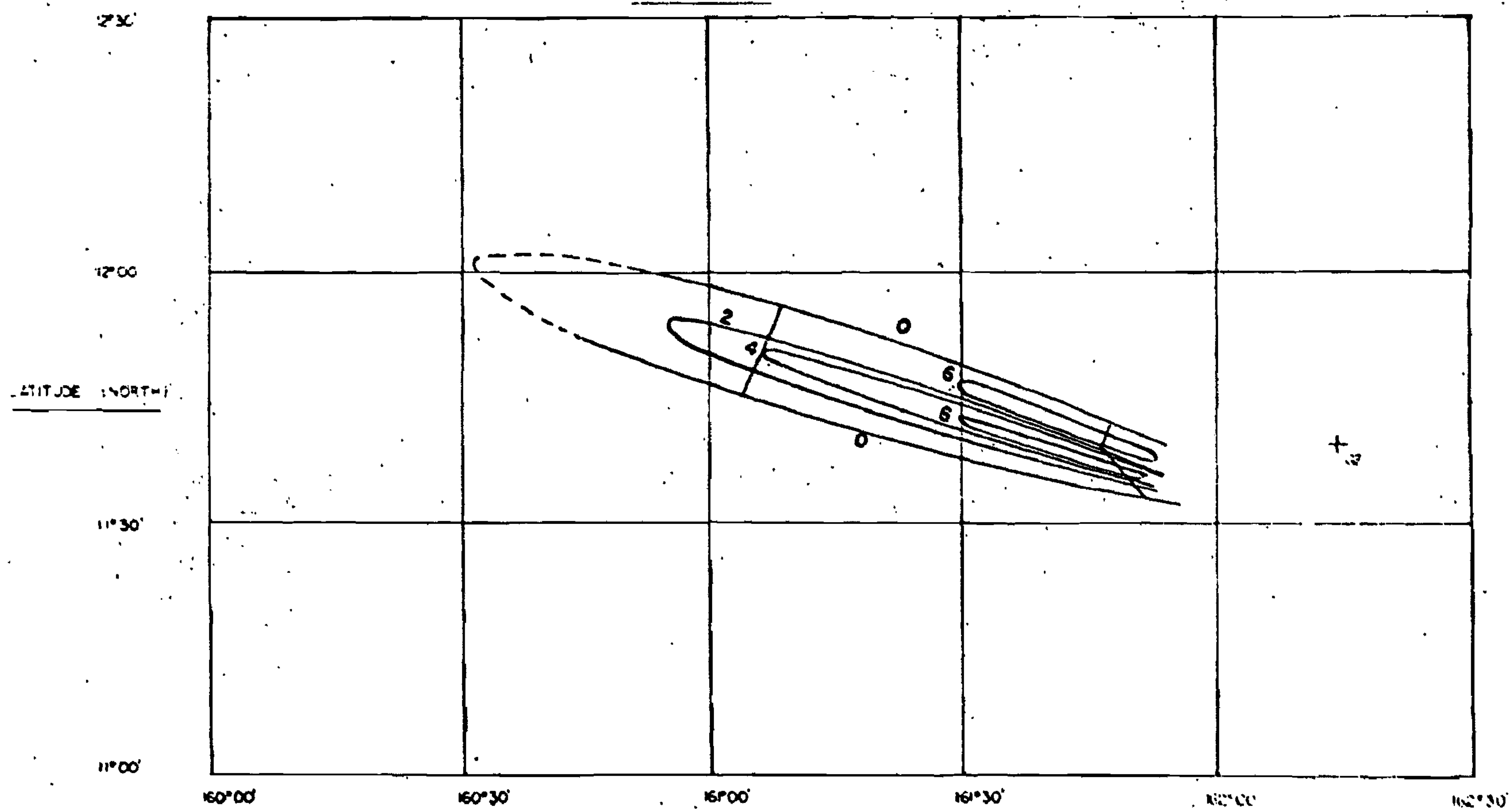
ISODOSE LINES BETWEEN TRACES ARE POSSIBLE CONDITIONS AND SHOULD BE CONSIDERED ILLUSTRATIVE ONLY

[redacted] [redacted]

Figure 16

NECTAR ISODOSE

WESTERN SECTOR



LONGITUDE (EAST)

NOTE - READINGS IN MR/HR EXTRAPOLATED TO SURFACE AND CORRECTED TO H+2 DAYS

ISODOSE LINES BETWEEN TRACES ARE POSSIBLE CONDITIONS AND SHOULD BE CONSIDERED ILLUSTRATIVE ONLY

[redacted]

[redacted]

Table 2 represents the computation of activity at times other than H+2 days.

Table 2

At H+1 days	1240 megacuries total fallout
2	540
7	121
100	5

Table 3 which for convenience has been divided into the northeast and western areas contains the computation of activity which fell into each of these zones.

Table 3

Fallout Calculations*
Nectar

Region	Mean Surface Radiation (mr/hr)	Curies/sq.cm ($x10^{-6}$)	Area (mi^2)	Megacuries
Northeast Area				
0-1	0.5	0.6	2130	42.5
1-2	1.5	1.4	936	43.5
2-3	2.5	2.2	414	30.8
3-4	3.5	3.0	83	8.4
4-5	4.5	3.8	14	1.9
> 5	5	4.2	3	0.4
			3580 sq.mi.	127.5 megacurie total
West Area				
0-2	1.0	1.0	524	17.5
2-4	3.5	3.0	184	18.6
4-6	5.3	4.5	87	13.0
> 6	6.5	5.5	35	4.2
			830 sq.mi.	53.3 megacurie total

* Referred to H+2 days.

Table 4 are the activities for other than H+2 days. The total sea water activity measurements of each of the tests are a measure of the relative yields of the devices.

Table 4

	Northeast	West
At H+1 days	293 megacuries total	122.0 megacuries total
2	127.5	53.3
7	28.3	11.8
100	1.2	0.5

EQUIPMENT

The apparatus used for determining the radiation level consisted of a high precision detector ratemeter assembly, Figure 17, with a wide dynamic range. The detector was a sodium iodide crystal 1-1/8" diameter x 1-1/2" high coupled to a 12-stage DuMont photomultiplier. The measuring circuit consisted of amplifiers and an anti-coincidence circuit which eliminated the effect of cosmic background. The anti-coincidence circuit was unnecessary considering the high activity levels which were measured. The ratemeter is capable of a range up to one million counts per second which precluded major resolution losses. The circuit, Figure 18 was powered from the 28 volt supply of the airplane. The output of the circuit was connected into an Esterline-Angus recorder operated at a chart speed of 12" per hour.

INTERPRETATION OF YANKEE SEA WATER ACTIVITY DATA

In the data taken by ship (1), after the YANKEE shot, it was found that the activity tended to diffuse downward in the water to the thermocline, approximately 400' below the sea water surface. Practically no lateral diffusion took place. From Figure 10,(2) it is evident that there is correlation between the surface measurement of activity and the total amount of activity deposited in the water, seemingly for any time from H-hour, the measurement of the surface activity either by aerial means or from the ship provided a means of evaluating the amount of activity in depth in the sea water.

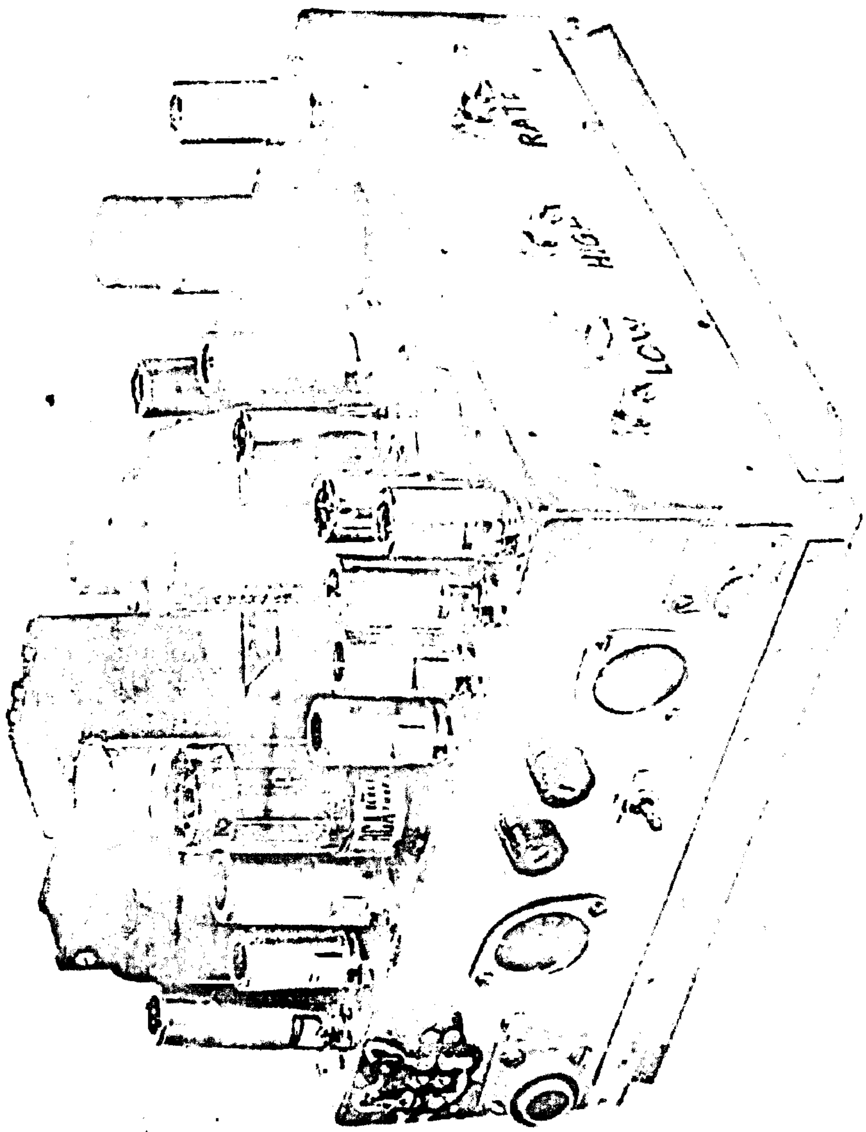
The water above the thermocline, due to wave and wind action is in a constant state of mixing and tends to distribute the activity in a fairly homogeneous manner. However, it would be expected that the peculiar type of turbulence exhibited there would be some zones with higher activity than adjacent zones mainly because the mixing is not complete and perfect with the present lack of precise data, it may be necessary to assume uniformity in order to evaluate a surface measurement, at any time after H-hour. Since this reasonable

(1) Scripps Institute of Oceanography by permission, U.S. NRDL supplied this data.

(2) See Appendix, Section IV

[redacted]

Figure 17



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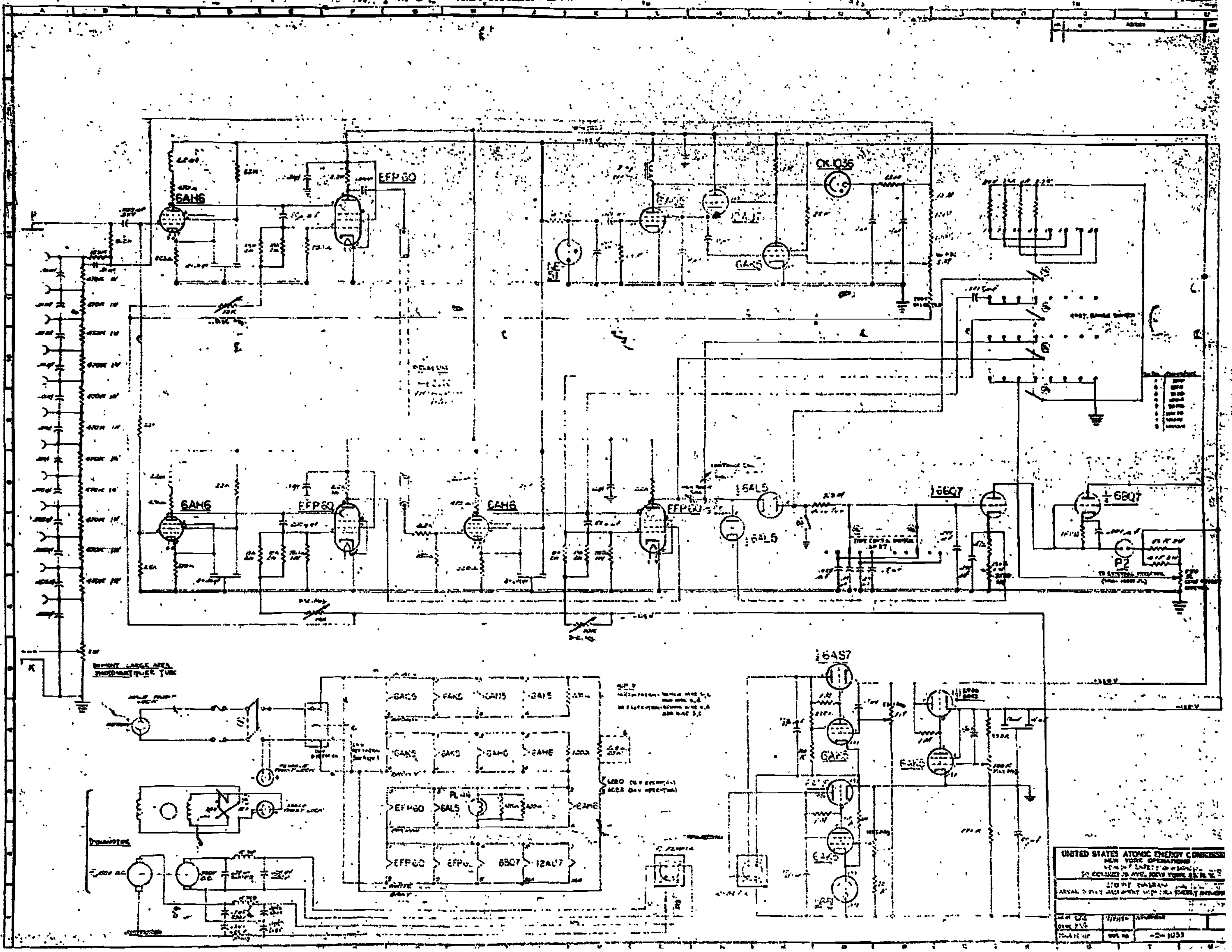
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CIRCUIT DIAGRAM
1033

it is possible by means of aerial measurements, to secure a figure for the amount of activity which would fall either on land or on the surface of a vessel and thereby ascertain the effective radiation level to persons who might be exposed to the radiation resulting from this activity. For example, one can assume that the maximum of trace B, Figure 3, was the zone of maximum fallout. Ninety-seven percent of the radiation reading on the surface is contributed by the first foot of water and an approximation indicates that multiplication of this radiation reading by four is the activity in each foot of water if there was no absorber. Since the activity had penetrated to a 400' depth almost uniformily, the surface reading can be multiplied by 1600 to give the value of radiation flux if all the activity were concentrated in a layer on land. Extrapolation back to H+12 hours require multiplication by a factor of five so that the radiation flux at H+12 hours, if all the activity had been deposited on land was in the order of 240 roentgens per hour.

CONCLUSIONS

The technique seems to be quite feasible in light of the excellent correspondence of all data although more information is required in order to firmly fix the conditions of the phenomena. Since this technique will materially aid the evaluation of fallout for Civil Defense and since it will be of major importance to direct naval facilities away from the zone of activity from a weapon, it would seem to be of special importance for further study. This technique, since the information is available promptly, permits the disposition of vessels so that they either may penetrate or remain out of the contaminated area, will permit deploying of ships for washdown to clean areas, and will also permit determination of the direction of the fallout debris trajectories for early warning where dangerous activity may fall on land or on vessels at sea.

RECOMMENDATIONS

For any future survey, based on the findings of this report, one could reasonably plan to secure the data needed. Since a 360° scan is desirable, four airplanes, in the air would be needed during the two or three days following shot time, to secure the minimum general coverage, rapidly and efficiently. Experience during the Castle operation indicates that it is not possible to conveniently communicate from plane to plane, nor is it feasible to reconstruct the pattern of fallout in the planes during flight. This can best be done through a central plotting group that receives the data at 15 minute intervals from each plane, assembles the information by plotting the corrected activity data as it comes in and then relaying information to the planes, in many cases to redirect the plane to a new area of interest.

The information in the plane is complex in character and since it must be interpreted it is suggested that the actual graphical data on the Esterline Angus charts in each of the planes be transmitted by telemeter (a minimum of 50 to 150 miles), C.W. transmission is indicated. A telemetering system

is in development here which will fulfill these needs and should operate within the capabilities of a military C.W. transmitter. The data transmitted should also include bearing, heading, altitude, ground speed and time between transmissions.

Since altitude attenuation is large it is essential to provide means of correcting the data for altitude variations during flight of the planes. A compensating unit is also in development and will be designed for attachment to a modern radio altimeter of the type now installed in new Military planes. The equipment described above is small and light weight and will not present problems of installation. Since the planes must operate with a minimal residual background, to be read in the survey meter, it will be necessary to decontaminate the planes on the ground, to provide shelter for the planes to avoid accidental contamination by fallout debris, and to provide shielding on the radiation sensitive part of the detection equipment so that a minimal effect of contamination will result.

It will be necessary to have a number of surface vessels available to measure and record surface activity, penetration of activity in depth, with time, and to secure samples of contaminated water for measurement at a Radiochemical Laboratory which should be located near test site headquarters. This will allow evaluation of short-lived activity of emitters such as Neptunium and with gamma ray spectrum analysis will result in information on the nature of the fission product mixture which will further permit evaluation of the aerial data in terms of the sea water activity.

INTRODUCTION TO APPENDIX

These Appendices are the raw data of this report. The conditions under which this data was taken, the inability to plan for the experiment as fully as one would like, and other factors made it desirable to present the data so that if any future rework was required, the basic information would not be lost.

APPENDIX

Section I

Altitude Absorption Correction

Table I is the data which is the basis for the altitude attenuation correction curve, Figure I, for fission product gamma radiation.

TABLE I

No.	Flight	Lat(N)	Long(E)	Mr/hr (Net)	Time (Z)	H+hrs.	f_t	Mr/hr (Net) @H+48	Alt.
a	Y-B	12-00	166-13	6.7	080234	80	1.87	12.5	200
b	N-B-1	12-04	162-16.8	0.9	141947	25	0.46	0.4	400
c	N-B-2	12-41.2	162-15	1.0	142010	26	0.48	0.48	300
d	N-B-3	12-35	162-16.3	0.9	142108	27	0.51	0.45	400
e	N-B-8	12-02.3	162-19	0.68	150012	30	0.57	0.39	400
a	Malola	12-00	166-13	40	060527	35	0.69	27.7	
b	"	12-04	162-16.8	2.55	150130	31	0.60	1.5	
c	"	12-41.2	162-15	1.8	150750	37½	0.75	1.4	
d	"	12-35	162-16.3	2.3	150700	37	0.74	1.7	
e	"	12-02.3	162-19	1.8	150750	37½	0.75	1.4	

No.	Alt.	f_a
a	200	2.2
b	400	3.8
c	300	2.9
d	400	3.8
e	400	3.6

TABLE I (Continued)

Helicopter Over Island

Location	Altitude	Mr/hr	f_a
William	3'	60	1.00
	100	42	1.43
	200	25	2.4
	400	14	4.3
	600	7	8.6
Yoke	3'	45	1.00
	100	31	1.45
	300	13	3.46
	500	8	5.63
Janet	3'	4	1.00
	200	2	2.00

Average of All Data

Alt.	f_a
0	1.0
100	1.41
150	1.67
200	2.00
300	2.82
400	4.00
500	5.63

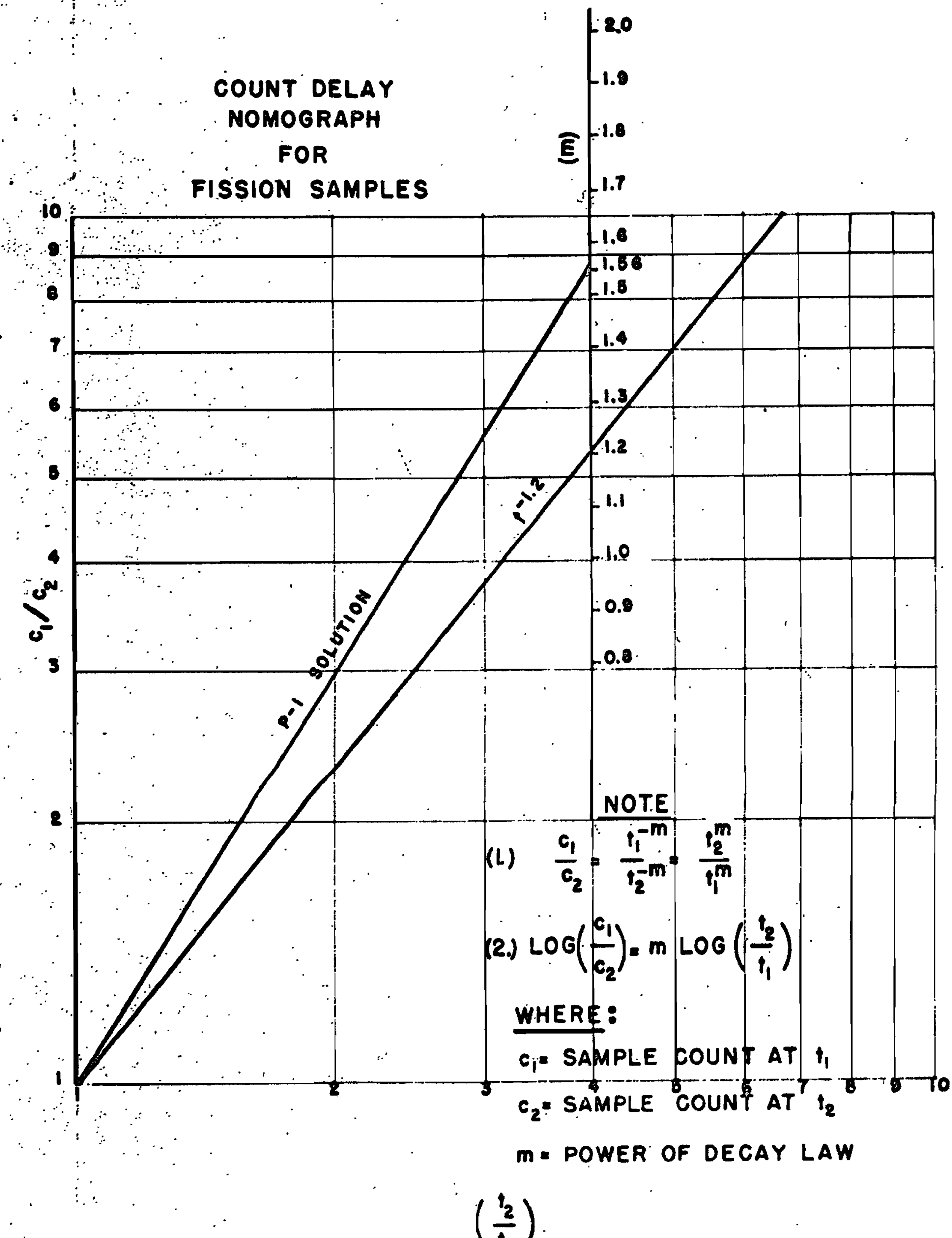

COUNT DELAY
NOMOGRAPH
FOR
FISSION SAMPLES
(m)
2.0
1.9
1.8
1.7
1.6
1.56
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
10
9
8
7
6
5
4
3
2
1
c1/c2
P-1 SOLUTION
t^-1.2
1
2
3
4
5
6
7
8
9
10
NOTE
(1) c1/c2 = t1^-m / t2^-m = t2^m / t1^m
(2.) LOG(c1/c2) = m LOG(t2/t1)
WHERE:
c1 = SAMPLE COUNT AT t1
c2 = SAMPLE COUNT AT t2
m = POWER OF DECAY LAW
(t2/t1)

FIGURE I

[redacted]

APPENDIX

Section II

Rate of Decay of Sea Water Activity - Castle Series

Yankee - Nectar:

Individual sea water samples were counted at specific time intervals and the rate of decay was determined as shown in Tables II and III. It was assumed that the decay scheme followed a power law in a general form:

$$A_1 = A_o\, t^{-\lambda}$$

In order to relate various counting data on a common nomograph:

for one time $A_1 = A_o t_1^{-\lambda}$

for a second time $A_2 = A_o t_2^{-\lambda}$

thus $$\frac{A_1}{A_2} = \frac{A_o t_1^{-\lambda}}{A_o t_2^{-\lambda}} = \frac{t_2^{\lambda}}{t_1^{\lambda}}$$

and $$\log (A_1/A_2) = \lambda \log (t_2/t_1)$$

A nomograph was constructed from this relationship, Figure I and the results indicate that on the average the decay of beta activity follows: $A = A_o t^{-1.2}$

Figures II and III and Table IV are based on this average law and give factors for converting from any time to H+2 days.

TABLE II

DECAY OF WATER SAMPLES NECTAR*

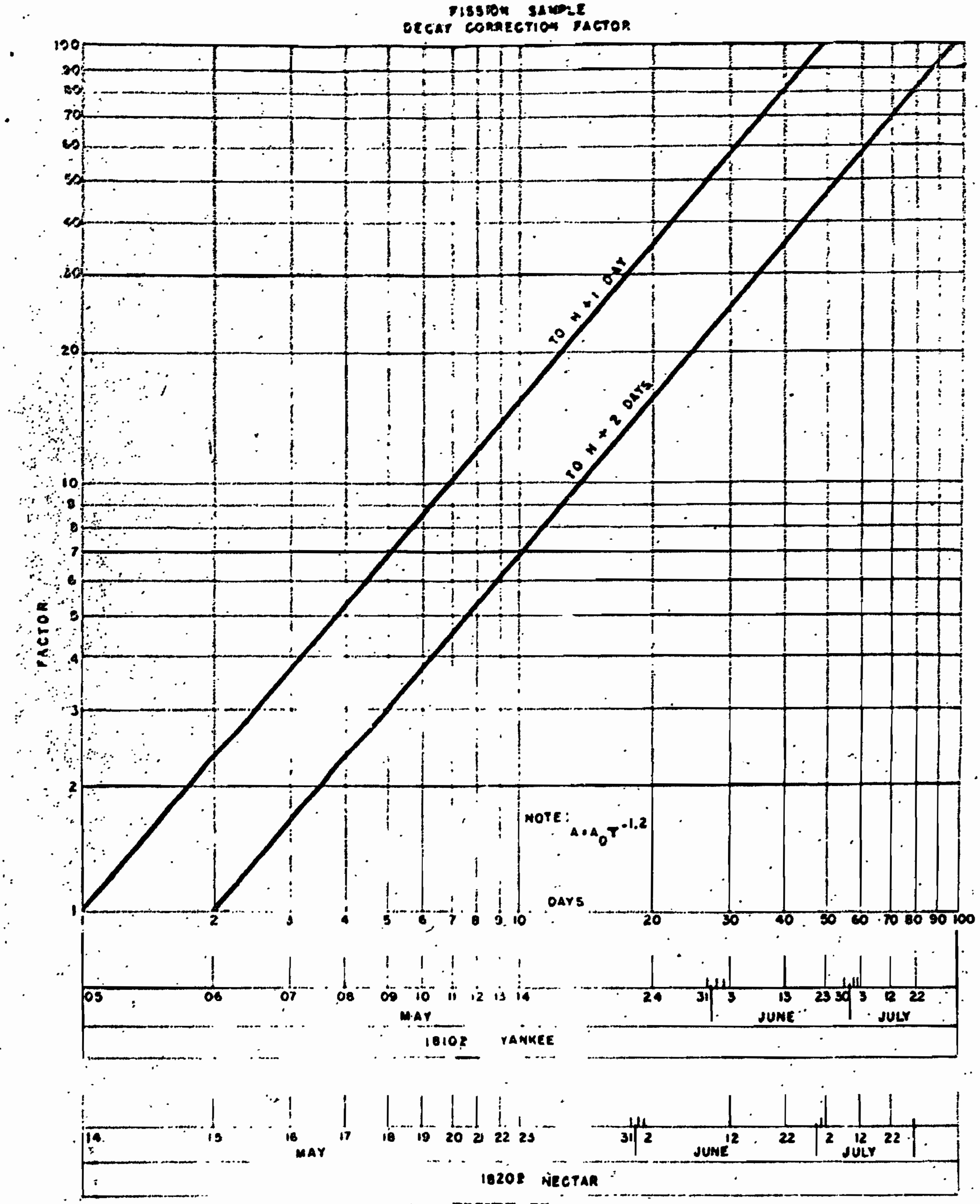
Z	Date	Time	H+ Days	Y-9 Sample		Surface(0200-9 May)	
130600	13 May	1200	11	F=1.0	%=100	F=1.0	%=100
150840	15 May	1440	13	1.1	91	1.2	83
180310	18 May	0910	16	1.9	52½	2.5	40
200330	20 May	0930	18	2.4	41½	3.4	29½
240330	24 May	0930	22	4.3	23	6.3	16
250430	25 May	1030	23	5.3	19	6.7	15

F to Correct to 13 May 1200

Sample Y-9 $I = I_o t^{-2.45}$

" Surface $I = I_o t^{-2.59}$

* Data obtained from NRDL



FISSION SAMPLE
DECAY CORRECTION FACTOR
FACTOR
TO H + 1 DAY
TO H + 2 DAYS
NOTE: $A = A_0 T^{-1.2}$
DAYS
MAY
JUNE
JULY
18102 YANKEE
18202 NECTAR

FIGURE II

FISSION SAMPLER
DECAY CORRECTION FACTOR
(TO H + 48)

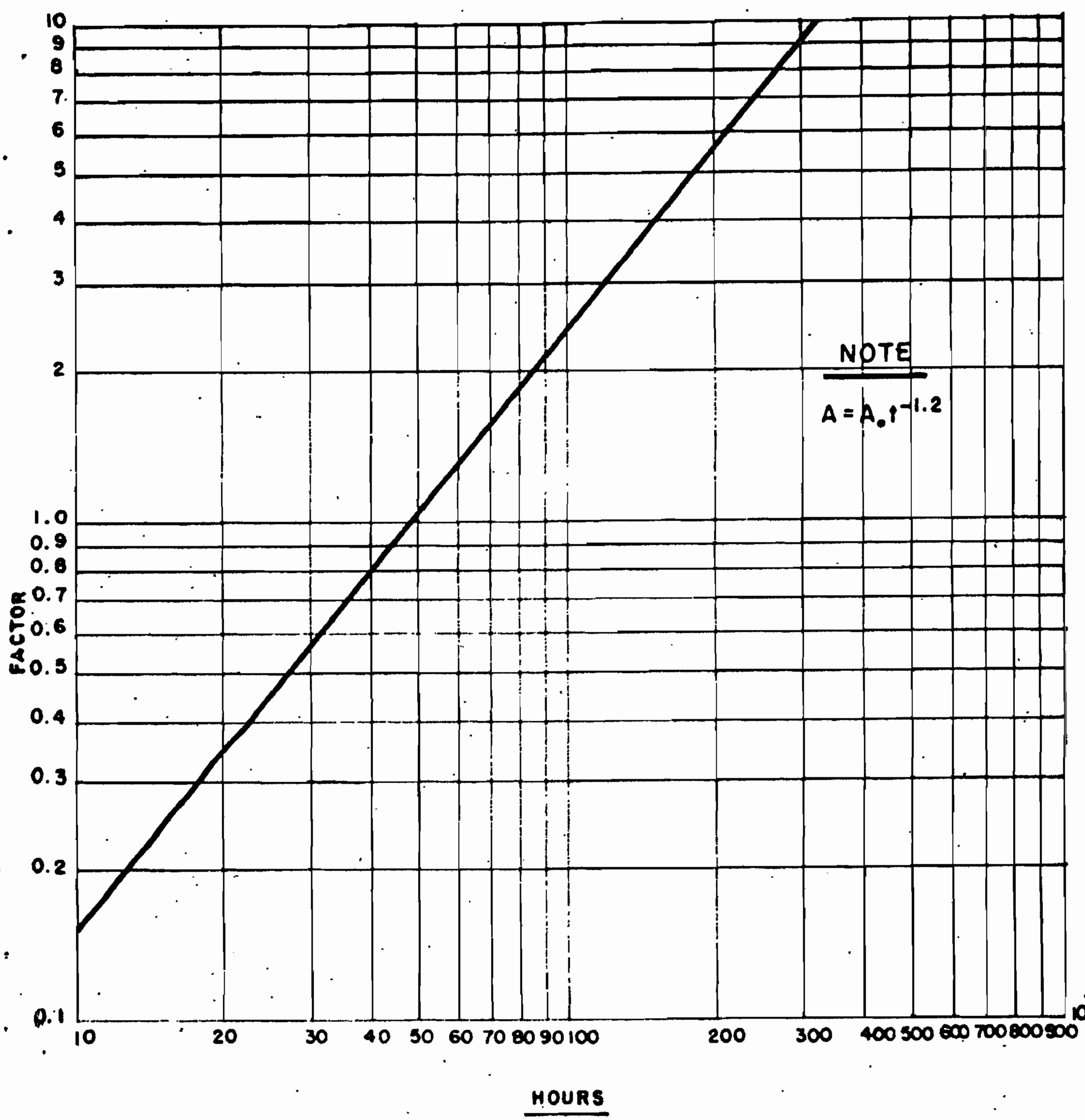


FIGURE III

TABLE III

COUNTING RESULTS OF SEA WATER ACTIVITY
NECTAR

Sample No.	Ship and No.	Particulate Beta (d/m/l)	Particulate Bo/Bx	Particulate t (days)	Particulate tx/to	Soluble Beta (d/m/l)	Soluble Bo/Bx	Soluble t (days)	Soluble tx/to
P-1	M-1	-		-		150,000	1.00	21	1.00
						48,000	3.13	44	2.10
P-21	M-21	200,000	1.00	13	1.00	230,000	1.00	21	1.00
		2,200	9.10	51	3.93	44,000	5.22	44	2.10
P-55	M-39	16,000	1.00	14	1.00	5,300	1.00	21	1.00
		2,860	5.60	51	3.64	2,200	2.41	51	2.43
P-69	M-45	3,900	1.00	14	1.00	9,100	1.00	21	1.00
		760	5.13	51	3.64	6,000	1.52	44	2.10
						4,800	1.90	51	2.40
						3,060	2.97	72	3.43
P-27	S-27	7,500	1.00	13	1.00	18,000	1.00	20	1.00
		2,200	3.41	51	3.93	8,100	2.22	45	2.25
P-29	S-29	7,600	1.00	13	1.00	84,000	1.00	20	1.00
		2,170	3.50	51	3.93	5,800	1.45	44	2.20
						4,800	1.75	51	2.55
P-31	S-31	2,800	1.00	13	1.00	3,000	1.00	20	1.00
		810	3.46	51	3.93	900	3.34	72	3.60
P-35	S-35	1,500	1.00	13	1.00	3,000	1.00	20	1.00
		405	3.70	51	3.93	950	3.16	72	3.60
P-43	S-43	2,900	1.00	13	1.00	1,900	1.00	20	1.00
		560	5.18	51	3.93	652	2.91	72	3.60

[redacted]

TABLE IV

EXPONENT FOR DECAY OF SEA WATER SAMPLES UNDERNEATH NECTAR

Sample No.	Particulate (t^{-m})	Soluble (t^{-m})
P-1	-	1.56
P-21	1.6	0.92
P-55	1.31	0.98
P-69	1.26	1.32
P-27	0.89	0.98
P-29	0.91	2.82
P-31	0.91	1.27
P-35	0.95	0.89
P-43	1.2	0.82

$$\text{Average} = \frac{20.59}{17} = 1.21$$

$$A = A_o t^{-1.2}$$

APPENDIX

Section III

Wind Trajectory Data - Castle Series

Yankee - Nectar:

The data of Table V indicates the probable direction of a particle which, starting from ground zero position at a specific altitude, would have a trajectory resulting from the vectorial addition of the wind trajectories shown on Figures 4 and 7.

TABLE V

	YANKEE		NECTAR	
USS Curtis 11.2 N 165.9 E	May 5, 1954 0610 Local		Eniwetok Island	May 14, 1954 0558 Local
Altitude 1,000 Ft.	Degrees	Knots	Degrees	Knots
Surface	080	24	090	19
1	070	23	090	21
1.5	075	24	100	20
2	080	25	100	17
3	080	24	110	19
4	080	23	110	14
5	070	20	110	15
6	070	20	110	14
7	070	18	100	12
8	070	11	100	10
9	040	06	110	11
10	020	05	110	14
12	010	05	120	17
14	340	05	110	18
16	320	13	130	12
18	280	09	140	12
20	290	14	130	08
25	230	23	140	06
30	270	34	230	17
35			210	09
40			210	29
45	280	56	230	32
50	250	44	280	35
51			240	38
52	200	46		

[redacted]

APPENDIX

Section IV

Depth Penetration Data - Castle Series

The area under each curve is directly related to the total activity in the water per unit area.

Table VI is a summary of the ratio of surface activity in counts per minute per square centimeter and the activity in the water in counts per minute per liter times 10^6. Table VII is the data corrected to H+48 hours. The correlation of the depth profiles of Figure IV are shown on Figure 10, the data is shown in Table VIII.

TABLE VI

NRDL - COUNTING DATA - YANKEE

Date Time (Mike)	Lat(N)	Long(E)	Sample	Depth Meters	Polyethylene Bottle C-T Pacific Coast	Polyethylene Bottle c/m/15ml	Nansen Sampler C-T Pacific Coast	Nansen Sampler c/m/15ml	Sea Rdg. mr/hr
050130	11-12	166-01.8	1-P	0	150951	BG		-	
				50	150959	"	151204	BG	
				100		"	151208	"	
				150			1212	"	
				250			1158	"	
				500			1201	"	
				800			1215	"	
061436	12-10	166-06	2-P	0	140954	3600	151431	9400	
				25	150939	5300	151426	6300	
				50	151003	4000	1548	8400	
				100	141000	400	1428	5600	
				175			1550	8500	
061638	12-05	166-08.5	3-P	0	141120	7900		-	38
061737	12-00	155-13	4-P	0	141122	7300		-	40
061840	11-55.3	166-16.6	5-P	0	140957	3700		-	
				25	1322	3600	201105	2400	
				50	1315	3300	1047	2100	
				100	1318	190	0949	210	
				175	0950	250	1034	40	
				500			1022	BG	
070130	11-51	167-04.2	6-P	0	141331	280			

TABLE VI (Continued)

Date Time (Mike)	Lat(N)	Long(E)	Sample	Depth Meters	Polyethylene Bottle C-T Pacific Coast	Polyethylene Bottle c/m/15ml	Nansen Sampler C-T Pacific Coast	Nansen Sampler c/m/15ml	Sea Rdg. mr/hr
070500	12-19.4	166-57.2	7-P	0	-	1300	151422	1600	
				25	131251	1900	200946	1100	
				50	1503	2000	1000	980	
				100	1305	1600	1057	1200	
				175	1246	120	1011	40	
071300	13-12	166-40	8-P	0	131346	50	-	30	
				25	140924	620	200953	120	
				50	1106	60	0956	140	
				100	0940	180	0942	140	
				175	131307	30	1106	40	
071607	13-00.3	167-00.5	9-P	0	141110	250			
071840	12-48	167-20	10-P	0	141117	240	-	150	
				25	0935	510	201030	320	
				50	1005	310	1026	400	
				100	0930	770	1017	180	
				175	0935	180	1110	150	
072225	12-30	167-35	11-P	0	141114	440	-	300	
				25	1325	740	151119	310	
				50	1350	440	1115	310	
				100	1100	400	1140	250	
				200	0938	460	1052	300	
				500	-	-	1143	30	
080410	12-03.5	168-00.5	12-P	0	141346	30			
080805	12-32	168-08	13-P	0	150942	1200			
080900	12-45	168-10.1	14-P	0	150948	400			
081000	12-45	168-16	15-P	0	150954	1300			
081100	12-43.5	168-21	16-P	0	131510	350			
081200	12-43	168-25	17-P	0	131522	150			
081350	12-58	168-27.5	18-P	0	131517	940			
081445	12-59.6	168-26.6	19-P	0	131352	580	151107	450	
				25	140946	740	1112	380	
				50	131525	510	1146	460	
				100	1454	640	1137	290	
				200	1343	50	1123	20	
				500	-		1127	20	
090200	12-19	166-39.5	20-P	0	131351	4700			
090400	12-08	166-10.5	21-P	0	131520	1100			
090600	12-02.5	165-44	22-P	0	141353	4600			
091310	12-01	165-16	23-P	0	131400	760			
091525	11-52	165-34	24-P	0	131244	4400	151417	3900	
				25	1329	4700	201049	3500	
				50	1402	8400	1055	4700	
				100	1459	890	1104	3500	
				200	1341	170	1050	560	
				500			1101	50	

DEPTH PROFILES YANKEE

[redacted]

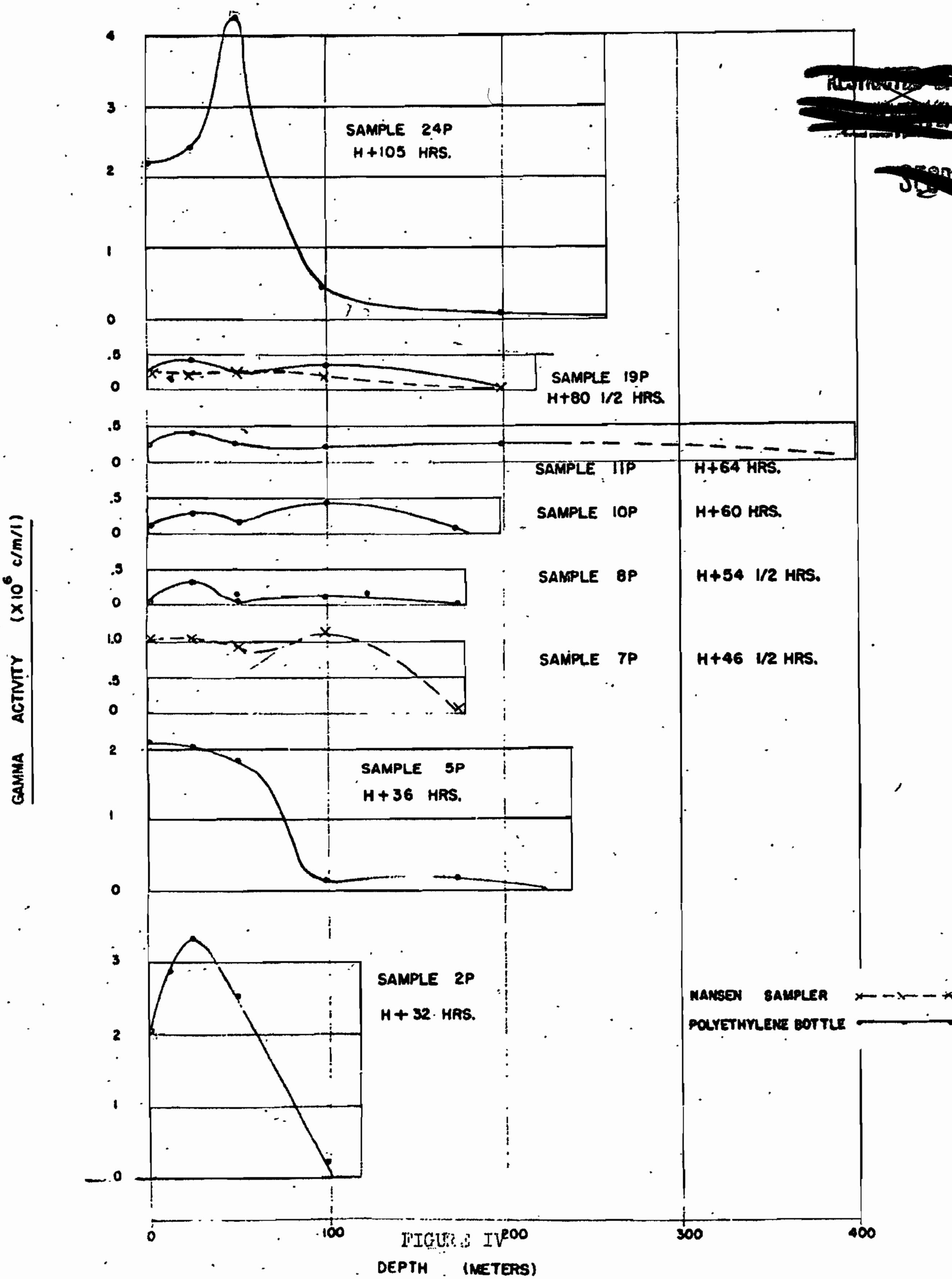


FIGURE IV

TABLE VII

CORRECTED COUNTING DATA - YANKEE

			Polyethylene Bottle			Nansen Sampler		
Sample	Time (Z)	Depth	C-T	c/m/15ml ($x10^3$)	c/m/l ($x10^6$)	C-T	c/m/15ml ($x10^3$)	c/m/l ($x10^6$)
1-P	042230	0	13	BG	BG	-	BG	BG
		50	"	"	"	13	"	"
		100		"	"	"	"	"
		150				"	"	"
		250				"	"	"
		500				"	"	"
		800				"	"	"
2-P	060236	0	12	30.2	2.02		88.5	5.90
		25	13	50	3.34		59.2	3.95
		50	13	37.6	2.51		79	5.28
		100	12	3.4	0.237		52.6	3.51
		175					80	5.35
3-P	060438	0	12	66.4	4.43			
4-P	060537	0	12	61.4	4.09			
5-P	060640	0	12	31.1	2.08			
		25	"	30.2	2.02	18	33.6	2.24
		50	"	27.8	1.85	"	29.4	1.96
		100	"	1.6	0.11	"	2.9	0.19
		175	"	2.1	0.14	"	0.6	0.04
		500				"	BG	BG
6-P	061330	0	12	2.36	0.16			
7-P	061700	0				13	15	1.00
		25	11	14.5	0.97	18	15.4	1.03
		50	"	15.2	1.01	"	13.7	0.91
		100	"	12.2	0.81	"	16.8	1.12
		175	"	0.9	0.06	"	0.6	0.04
8-P	070100	0	11	0.4	0.03			
		25	12	5.2	0.35	18	1.7	0.11
		50	"	0.5	0.03	"	2.0	0.13
		100	"	1.5	0.10	"	2.0	0.13
		175	11	0.3	0.02	"	0.6	0.04
9-P	070640	0	12	2.1	0.14			
10-P	070640	0	12	1.9	0.12			
		25	"	4.3	0.29	18	4.5	0.30
		50	"	2.6	0.17	"	5.6	0.37
		100	"	6.5	0.43	"	2.5	0.17
		175	"	1.5	0.10	"	2.1	0.14

TABLE VII (Continued)

			Polyethylene Bottle			Nansen Sampler		
Sample	Time (Z)	Depth	C-T	c/m/15ml ($x10^3$)	c/m/l ($x10^6$)	C-T	c/m/15ml ($x10^3$)	c/m/l ($x10^6$)
11-P	071025	0	12	3.7	0.25			
		25	"	6.2	0.41	13	2.9	0.19
		50	"	3.7	0.25	"	2.9	0.19
		100	"	3.4	0.23	"	2.3	0.15
		200	"	3.9	0.26	"	2.8	0.19
		500				"	0.3	0.02
12-P	071610	0	12	0.3	0.02			
13-P	072005	0	13	11	0.73			
14-P	072100	0	13	3.8	0.25			
15-P	072200	0	13	12	0.80			
16-P	072300	0	11	2.7	0.18			
17-P	080000	0	11	1.1	0.07			
18-P	080150	0	11	7.1	0.47			
19-P	080245	0	11	4.4	0.29	13	4.2	0.28
		25	12	6.2	0.41	"	3.6	0.24
		50	11	3.9	0.26	"	4.3	0.29
		100	"	4.9	0.33	"	2.7	0.18
		200	"	0.4	0.03	"	0.2	0.01
		500				"	0.2	0.01
20-P	081400	0	11	36	2.40			
21-P	081600	0	11	8.4	0.56			
22-P	081800	0	12	38	2.54			
23-P	090110	0	11	5.8	0.39			
24-P	090325	0	11	33	2.20	13	38	2.54
		25	"	36	2.40	18	49	3.27
		50	"	63.9	4.25	"	66	4.40
		100	"	6.8	0.45	"	49	3.27
		200	"	1.3	0.09	"	7.8	0.52
		500				"	0.7	0.05

[redacted]

TABLE VIII

Sample	Surface c/m/l (x10^6)	Area c/m/cm^2 (x10^6)
2-P Poly.	2.01	2.40
5-P Poly.	2.08	2.38
7-P Nansen	1.00	1.55
8-P Poly.	0.03	0.18
10-P Poly.	0.13	0.58
11-P Poly.	0.25	0.73
19-P Nansen	0.28	0.41
19-P Poly.	0.29	0.57
24-P Poly	2.20	2.62

$$\gamma\,(10^6\ \text{c/m/cm}^2) = 1.01\ \gamma\,(10^6\ \text{c/m/l}) + 0.34$$

[redacted]

APPENDIX

Section V

Correlation of Sea Water Activity to Gamma Dose Rate - Castle Series

Nectar:

Table IX are the readings of activity on the bridge taken from the USS Molola. Table X were readings taken on the USS Sioux. Table XI is the summary of data taken on sea water samples from both the Molola and the Sioux and represents both NYOO and NRDL counting data. Table XII is the correction of radiation reading on the ship to H+48 hours. The equivalent data of the USS Sioux is so low in gamma activity as to be not significant.

Figure 13 is the plot of the correlation of sea water activity to gamma dose rate.

[redacted]

[redacted]

TABLE IX

USS MOLOLA
POSITION LOG - NECTAR

Bottle No.	Lat.(N)	Long.(E)	Time (Mike)	Mr/hr Bridge
1-2	12-04	162-18	5/15 1333	2.6
3-4	12-03.6	162-13.6	1406	2.5
5-6	12-08.1	162-16.2	1430	2.6
7-8	12-11.6	162-18.9	1455	1.8
9-10	12-14.6	162-15.0	1520	2.2
11-12	12-20.2	162-15.8	1558	4.8
13	12-20.6	162-16.3	1602	4.8
14	12-21.2	162-18.2	1740	4.2
15-16	12-24.0	162-15.9	1808	2.6
17-18	12-25.4	162.15.8	1814	2.6
19-20	12-26.0	162-15.9	1819	3.0
21-22	12-28.8	162-15.2	1835	2.8
23-24	12-29.7	162-15.3	1840	2.7
25-26	12-33.5	162-15.0	1900	2.6
27-28	12-38.7	162-14.9	1925	1.8
29-30	12-45.7	162-14.8	1950	1.8
31-32	12-51.0	162-14.2	2015	1.6
33-34	12-55.9	162-13.8	2040	1.3
35-36	13-00.0	162-14.5	2105	0.8
37-38	13-00.0	162-19.0	2130	0.8
39-40	13-00.0	162-23.7	2155	0.6
41-42	13-00.0	162-28.2	2220	0.6
43-44	12-56.9	162-30.0	2245	0.7
45-46	12-51.5	162-29.9	2310	0.6
47-48	12-46.5	162-29.9	2335	0.6
49-50	12-41.1	162-29.8	2400	0.8
51-52	12-35.8	162-29.8	5/16 0025	2.6
53-54	12-30.4	162-29.7	0050	2.5
55-56	12-25.5	162-29.9	0115	2.0
57-58	12-20.4	162-29.6	0140	1.6
59-60	12-15.0	162-29.3	0205	1.0
61-62	12-10.0	162-29.2	0230	1.0
63-64	12-04.9	162-29.2	0255	0.8
65-66	12-00.0	162-29.0	0320	0.7
67-68	11-54.6	162-28.9	0345	0.4
69-70	11-49.2	162-28.8	0410	0.4
71-72	11-44.1	162-28.7	0435	0.4

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TABLE X

USS SIOUX
POSITION LOG - NECTAR

Bottle No.	Lot (N)	Long (E)	Time	Mr/hr (overside)
1	13°- 26½	161°- 49.2	15 May, 1725	.8
2-3	13 - 30½	161 - 46.3	1800	.8
4-5	12 - 35.2	161 - 47.6	1830	.6
6-7	13 - 40.2	161 - 48.8	1900	.8
8-9	13 - 45.5	161 - 49.7	1930	.8
10-11	13 - 51	161 - 49.7	2000	.5
12-13	13 - 56	161 - 49.7	2030	.5
14-15	13 - 58.5	161 - 50.8	2100	.5
16-17	14°- 00.0	161 - 54.7	2130	.5
18-19	14 - 01	162 - 00.0	2200	.5
20-21	13°- 56	162 - 03.0	2230	.4
22-23	13 - 51.7	162 - 06.0	2300	.4
24-25	13 - 47.3	162 - 08.6	2330	.4
26-27	13 - 42.7	162 - 11.6	2400	.4
28-29	13 - 38	162 - 14.7	16 May, 0030	.4
30-31	13 - 33.2	162 - 17.6	0100	.4
32-33	13 - 29	162 - 20.5	0130	.4
34-35	13 - 24.2	162 - 23.2	0200	.4
36-37	13 - 20	162 - 26.2	0230	.4
38-29	13 - 15.2	162 - 29	0300	.4
40-41	13 - 11	162 - 32	0330	.4
42-43	13 - 06.3	162 - 34.3	0400	.5
44-45	13 - 01.8	162 - 33	0430	.3
46-47	12 - 56.8	162 - 31.6	0500	.3
48	12 - 52	162 - 30.	0530	1.1

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TABLE XI

SEA WATER SAMPLES - NECTAR

		Particulate			MFP			NYOO Total	NRDL			
Bottle	NYOO No.	d/m/l x10^3	Count Date	d/m/l x10^6 @t=2 d	d/m/l x10^3	Count Date	d/m/l x10^6 @t=2 d	d/m/l x10^6 @t=2 d	c/m/15ml	Count Date	c/m/15ml @t=2 d	c/m/l x10^3 @t=2 d
M-1	P-1	140	12d.	1.18	150	19d.	2.2	3.38				
3	P-3	83	"	0.70	110	"	1.61	2.31				
5	P-5	100	"	0.84	82	"	1.20	2.04				
7	P-7	120	"	1.01	58	"	0.85	1.86				
9	P-9	170	"	1.43	78	"	1.14	3.57				
11	P-11	180	"	1.51	250	"	3.65	5.16				
13	P-13	270	"	2.27	140	"	2.04	4.31				
15	P-15	34	"	0.29	100	"	1.46	1.75				
17	P-17	260	13d.	2.42	110	"	1.6	3.02				
19	P-19	86	"	0.80	120	"	1.75	2.55				
21	P-21	200	"	1.86	230	20d.	3.61	5.47				
23	P-23	160	"	1.49	180	"	2.82	4.31				
25	F-51	94	"	0.87	150	21d.	2.49	3.36	2116	7d.	9300	620
									2387	"	10500	700
27	P-67	130	"	1.21	320	15d.	3.58	4.79				
									1974	"	8700	580
29	P-53	210	"	1.95	160	21d.	2.66	4.61	1491	"	6560	438
									1253	"	5520	368
31	P-63	94	"	0.87	55	"	0.91	1.78				
									1000	"	4400	293
33	P-59	46	"	0.43	60	"	1.00	1.43	797	"	3510	234
									673	"	2960	197
35	P-65	60	"	0.56	24	"	0.40	0.96	164	"	721	48
37	P-61	42	"	0.39	9.2	"	0.15	0.54	106	"	466	31
39	P-55	16	14d.	0.16	5.3	22d.	0.09	0.26	37	"	163	10.9
									55	"	242	16.1
41	P-119	2	"	0.02	4.6	21d.	0.08	0.10				
43	P-57	8.5	"	0.09	6.4	"	0.11	0.20	52	"	229	15.2
									42	"	185	12.3
45	P-69	3.9	"	0.04	9.1	20d.	0.14	0.18				

TABLE XI (Continued)

Bottle	NYOO No.	Particulate d/m/1 x10^3	Particulate Count Date	Particulate d/m/1 x10^6 @t=2 d	MFP d/m/1 x10^3	MFP Count Date	MFP d/m/1 x10^6 @t=2 d	NYOO Total d/m/1 x10^6 @t=2 d	NRDL c/m/15ml	NRDL Count Date	NRDL c/m/15ml @t=2 d	NRDL c/m/1 x10^3 @t=2 d
47	P-49	24	13d.	0.22	22	22d.	0.39	0.61				
49	P-81	100	"	0.93	39	"	0.68	1.61	520	7d.	2285	152
									395	"	1760	117
51	P-99	250	14d.	2.52	140	"	2.45	4.97	2745	"	12100	806
									4741	"	20800	1390
53	P-97	160	"	1.62	160	"	1.80	4.42				
									3251	"	14300	950
55	P-103	480	"	4.85	140	"	2.45	7.30	2918	"	12800	855
									2467	"	10900	725
57	P-85	200	13d.	1.86	80	"	1.4	3.26	1475	"	6490	432
59	P-91	23	14d.	0.23	67	"	1.17	1.50	662	"	2910	196
									651	"	2860	190
61	P-79	73	13d.	0.68	23	21d.	0.38	1.06	343	"	1510	100
									390	"	1720	114
63	P-87	36	14d.	0.36	24	22d.	0.42	0.78	394	"	1730	116
65	P-93	6.8	"	0.07	7.4	"	0.13	0.20				
									104	"	460	30.6
67	P-89	3.4	"	0.03	1.4	"	0.02	0.05	10	"	44	2.9
									36	"	160	10.6
69	P-75	3.3	"	0.03	2.8	21d.	0.04	0.07	15	"	66	4.4
									0	"	0	0
71	P-73	3.3	"	0.03	0.88	"	0.015	0.05	36	"	159	10.6
									11	"	48	3.2
S-1	P-77	1.8	"	0.018	1.4	"	0.023	0.041	17	"	75	5
3	P-71	0.84	"	0.008	1.6	"	0.027	0.035				
5	P-83	1.9	13d.	0.018	3.1	22d.	0.054	0.072				
7	P-95	0.31	14d.	0.003	3.1	"	0.054	0.057				
									4	"	17.6	1.17
9	P-111	1.7	"	0.017	3.1	"	0.054	0.071				
11	P-101	1.6	"	0.016	7.3	"	0.128	0.144				
13	P-109	1.1	"	0.011	2.0	"	0.035	0.046				
15	P-105	0.54	"	0.005	6.9	"	0.121	0.126				

TABLE XI (Continued)

Bottle	NYOO No.	Particulate d/m/1 x10^3	Particulate Count Date	Particulate d/m/1 x10^6 @t=2 d	MFP d/m/1 x10^3	MFP Count Date	MFP d/m/1 x10^6 @t=2 d	NYOO Total d/m/1 x10^6 @t=2 d	NRDL c/m/15ml	NRDL Count Date	NRDL c/m/15ml @t=2 d	NRDL c/m/1 x10^3 @t=2 d
17	P-117	13.0	14d.	0.131	3.6	22d.	0.063	0.394	39	7d.	172	11.5
									41	"	180	12
19	P-107	1.2	"	0.012	3.4	"	0.059	0.071	8	"	35	2.3
									6	"	26.4	1.8
21	P-115	3.6	"	0.036	2.2	"	0.039	0.075	40	"	176	11.7
									43	"	189	12.6
23	P-113	1.6	"	0.016	6.9	"	0.120	0.136				
25	P-25	4.9	13d.	0.046	11	20d.	0.170	0.216				
27	P-27	7.5	"	0.070	18	"	0.282	0.352				
29	P-29	7.6	"	0.071	.084	"	0.0013	0.072				
S-31	P-31	2.800	"	0.026	3	"	0.047	0.073				
33	P-33	0.95	"	0.009	2.5		0.039	0.048				
35	P-35	1.5	"	0.014	3.0		0.047	0.061				
37	P-37	2.5	"	0.023	2.0		0.031	0.054				
39	P-39	2.9		0.027	2.1		0.033	0.060				
41	P-41	0.68	"	0.006	1.8		0.028	0.034				
43	P-43	2.9		0.027	1.9		0.030	0.057				
45	P-45	5.7		0.053	5.4		0.085	0.138				
47	P-47	260	"	2.42	150		2.36	4.78				
48												

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TABLE XII

USS MOLOLA

Sample	Mr/hr	Reading Time Hrs.	Factor	Corr. to H+48 hrs (mr/hr)
M-1	2.6	31	0.60	1.56
3	2.5	31½	0.61	1.52
7	1.8	32½	0.63	1.13
9	2.2	33	0.64	1.4
11	4.8	33½	0.65	3.12
13	4.8	33½	0.65	3.12
14	4.2	35	0.69	2.9
15	2.6	35½	0.70	1.82
17	2.6	35-3/4	0.705	1.83
19	3.0	36	0.71	2.13
21	2.8	36	0.71	1.99
23	2.7	36	0.71	1.92
25	2.6	36½	0.72	1.87
27	1.8	37	0.74	1.33
29	1.8	37½	0.75	1.35
31	1.6	38	0.76	1.21
33	1.3	38	0.76	0.98
35	0.8	38½	0.78	0.62
37	0.8	39	0.79	0.63
39	0.6	39½	0.80	0.48
41	0.6	40	0.81	0.49
43	0.7	40	0.81	0.57
45	0.6	40½	0.82	0.49
47	0.6	41	0.83	0.50
49	0.8	41½	0.85	0.68
51	2.6	42	0.86	2.24
53	2.5	42½	0.87	2.18
55	2.0	43	0.89	1.78
57	1.6	43	0.89	1.42
59	1.0	43½	0.90	0.9
61	1.0	44	0.91	0.91
63	0.8	44½	0.92	0.74
65	0.7	45	0.93	0.65
67	0.4	45	0.93	0.37
69	0.4	45½	0.95	0.38
71	0.4	46	0.96	0.38

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APPENDIX

Section VI

Isodose Plot Data - Castle Series

Yankee - Nectar:

In Table XIII are the corrections to radiation level readings for H+48 hours and the sea surface. These are used to outline the isodose curve of Yankee. Table XIV are the computations for activity. Table XV is the data for Nectar. Table XVI are the isodose calculations for Nectar.

TABLE XIII

AERIAL DETECTOR SCALE CALIBRATION - YANKEE

Trace	Mr/hr (full scale)	Time (Z)	H+Hrs.	f_t	Mr/hr full scale @H+2 days	Alt (ft)	f_a	Mr/hr full scale @H+2 days on surface
A	13	071000	63½	1.4	18.2	150	1.7	31.0
B	13	080234	80	1.9	24.7	200	2.0	49.4
C	20	080315	81	1.9	3.8	70	1.27	48.7

TABLE XIV

ISODOSE CALCULATIONS - YANKEE

Region (mr/hr)	Mean Value (mr/hr)	Volume β Activity (d/m/l) x10^6	Area β Activity (d/m/cm^2) x10^6	Curies/cm^2 x10^{-6}	Area (mi)^2	Area (cm^2) x10^{12}	Curies x10^6
0 to 10	4.9	8.8	9.3	4.2	1223	41.0	172
10 to 20	14.7	26.2	26.8	12.2	496	16.5	202
20 to 30	24.1	42.8	43.6	19.8	196	6.6	131
Over 30	30	53.5	54.4	24.7	40	1.3	33
					1955		540

Note 1: Data referred to H+2 days
2: β (x10^6 d/m/l) = 1.78 R(mr/hr) ÷ 0.063
3: β (x10^6 d/m/cm^2) = 1.01 β (x10^6 d/m/l) + 0.34
4: Curies/cm^2 = β(d/m/cm^2)/2.2 x 10^{12}
5: Cm^2 = mi^2 3.35 x 10^{10}

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TABLE XV

AERIAL DETECTOR SCALE CALIBRATION - NECTAR

Flight	Trace	Mr/hr (full scale)	Time (Z)	H+hrs	f_t	Mr/hr (full scale) @ H+48 hrs	Alt.	f_a	Mr/hr (full scal @surface @H+48 hr
Baker	1	9.0	141950	25½	0.47	4.2	400	4.0	16.8
	2	9.0	149958	25½	0.47	4.2	400	4.0	16.8
	3	9.0	142104	25½	0.47	4.2	300	2.8	11.8
	4	9.0	142114	27	0.50	4.5	200	2.0	9.0
	5	9.0	142133	27	0.50	4.5	400	4.0	18.0
	6	9.0	142147	27½	0.51	4.6	400	4.0	18.4
	7	9.0	142352	29½	0.56	5.0	400	4.0	20.0
	8	9.0	150011	30	0.57	5.1	400	4.0	20.4
	9	9.0	150043	30 ⅓	0.58	5.2	400	4.0	20.8
	10	9.0	150256	32½	0.63	5.7	400	4.0	22.8
	11	9.0	150312	33	0.64	5.8	400	4.0	23.2
Dog	1	9.0	154927	49	1.03	9.3	400	4.0	37.2
	3	9.0	152024	50	1.07	9.6	400	4.0	38.4
	4	9.0	152035	50	1.07	9.6	400	4.0	38.4
	5	9.0	152057	50½	1.08	9.7	400	4.0	38.8
	6	9.0	152105	50½	1.08	9.7	400	4.0	38.8
	7	9.0	152219	52	1.11	10.0	400	4.0	40.0
	8	9.0	152238	52	1.11	10.0	400	4.0	40.0
	9	9.0	152328	53	1.14	10.2	400	4.0	40.8
	10	9.0	152355	53½	1.15	10.3	400	4.0	41.1
	11	9.0	160023	54	1.17	10.5	400	4.0	42.0

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TABLE XVI

ISODOSE CALCULATIONS - NECTAR

Region	Mean Value (mr/hr)	Volume β Activity (d/m/l) x10^6	Area β Activity (c/m/cm^2) x10^6	Curies/cm^2 x10^-6	Area (mi^2)	Area (cm^2) x10^12	Curies x10^6
Northeast							
0-1	0.5	0.95	1.3	0.6	2130	71	42.5
1-2	1.5	2.73	3.1	1.4	936	31	43.5
2-3	2.5	4.51	4.9	2.2	414	14	30.8
3-4	3.5	6.29	6.7	3.0	83	2.8	8.4
4-5	4.5	8.07	8.5	3.8	14	0.5	1.9
Over 5	5	8.9	9.3	4.2	3	0.1	0.4
					3580		127.5
West							
0-2	1.0	1.84	2.20	1.0	524	17.5	17.5
2-4	3.5	6.28	6.69	3.0	184	6.2	18.6
4-6	5.3	9.49	9.92	4.5	87	2.9	13.0
Over 6	6.5	11.64	12.12	5.5	35	1.2	4.2
					830		53.3

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APPENDIX

Section VII

Raft Program

INTRODUCTION

On April 5, 1954 the Instruments Branch was requested to develop a raft program to evaluate fallout debris activity levels in the seas adjacent to the shot site, to a radius of approximately 150 miles from ground zero. Although information from the Bravo Shot (1) indicated that the particulate matter would fall in a relatively narrow band, this program was improvised as a means to further delineate debris fallout paths and, as well, to determine whether a raft array could provide activity level data.

The sea water activity determination was found to be feasible during the flights on D+3. This raft data is included here to record the initial portion of the effort which lead to the findings.

EQUIPMENT

I. Rafts

Two types of rafts were utilized:

a. Styrafoam: These were made of styrafoam 3' wide x $4\frac{1}{2}$' long x 4" thick. See Figure V.

b. Plywood: The plywood rafts were fabricated by placing a sheet of plywood 4' x 6(x 5/16" thick on each side of two inner tubes placed end to end. The assembly was roped together using 500 pound break test manilla twine. See Figure VI.

II. Radiosonde

The radiosondes were simple one tube oscillators using 1L4 tubes powered by $1\frac{1}{2}$ volt filament batteries and 90 volt plate and screen supply batteries. The circuit was a colpitts oscillator using a standard broadcast band super heterodyne oscillator coil, The circuit was set up to be self modulating so that a modulated 1000 cycle note could be heard in the receivers. The output was to be coupled to a 50' antenna which was to be suspended from a 4' diameter helium filled "Gibson Girl" balloon. As a result of initial launching tests from a C-97 airplane it was evident that these balloons could not withstand the shock of launching.

The next attempt consisted of a bamboo mast approximately 12' long which was affixed to the radiosonde housing, a one gallon band can provided

(1) Private Communication, Major Luegien, U. S. Air Force.

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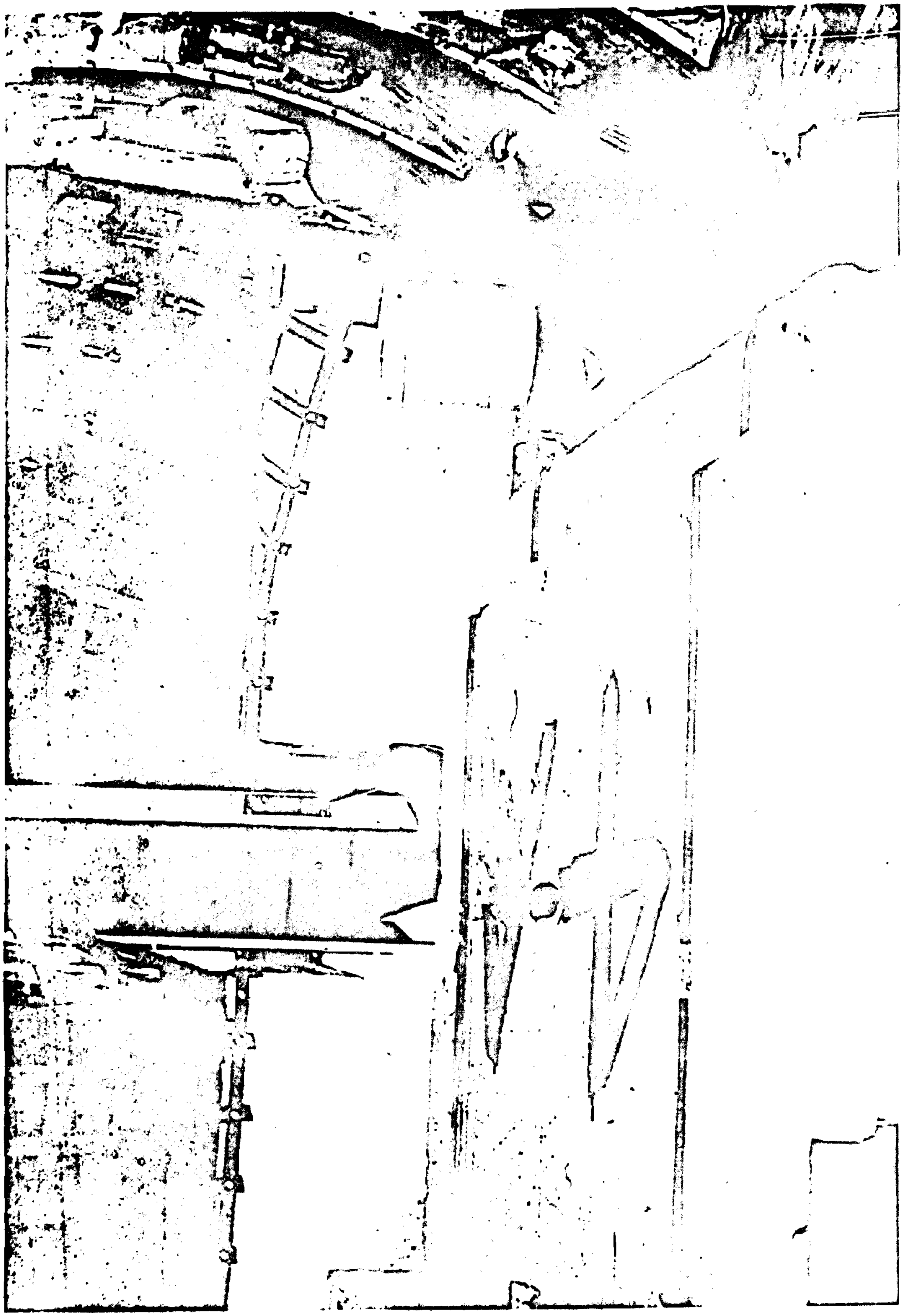

FIGURE V

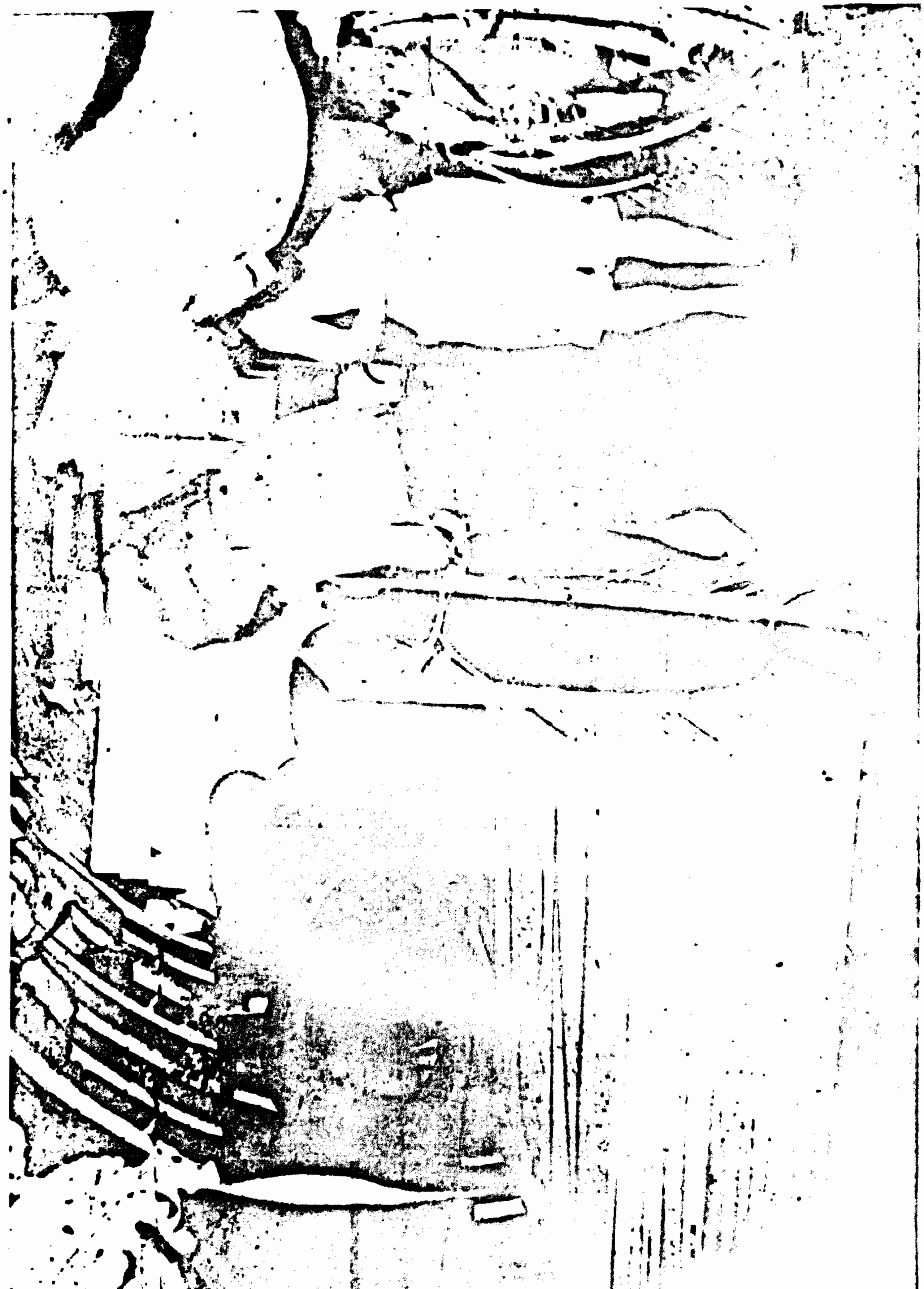

FIGURE VI

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with a hermetical seal for passage of the antenna lead connection. Two 2 pound weights were attached to a 2' portion of the bamboo pole which protruded beneath the radiosonde can. The buoyancy of the can and the buoyancy of the bamboo pole butt which projected into the water maintained the radiosonde can top 2" above the water and the weights on the end of the bamboo pole kept the pole reasonably erect. The antenna was strapped to the pole and each joint of the pole was taped since the poles could otherwise fail in tension at the joints, on launching.

The radiosonde-antenna unit could be launched with the plywood rafts but the shock of launching invariably destroyed the styrafoam rafts. A shock cord made of 1/2" diameter Bungee was fastened in a loop of the cable connecting the raft and the radiosonde together. The loop was about 4' in length so that the shock cord which was 12" long stretched during launching to take up the major portion of the energy produced by launching rafts when the plane was traveling at 180 knots.

The sea anchor described below, was originally specified in order to eliminate the drift one would expect from the freeboard of the rafts and the pull of the balloons each of which presented a great area to the prevailing winds. With the elimination of the radiosonde balloon the sea anchor was considered to be unnecessary.

III. Sea Anchor

The sea anchor consisted of a steel plate 18" square x 1/4" thick, with 4 grommeted holes to which were attached 4 ropes. Each rope was affixed to the corner of the raft.

RAFT LAUNCHING

The rafts were to be launched from a C-97 airplane through a chute which protruded through the rear loading doors, Figure VII.

After discussions with the responsible officer of the plane squadron designated to service this operation, it was evident that rectangular raft grid or any other individual unit configuration would not be satisfactory. It was decided that 300 rafts should be laid in a 90° sector starting at 30 miles from ground zero, the heading was to be determined at H+6 hours based on the predicted high altitude particle trajectory. The rafts were to be laid in clusters of 10 units in lines of 5 clusters per heading. Two planes were used for the operation, the first starting at 30 miles from ground zero, the second at 60 miles, each proceeding on alternate paths at 25 mile intervals in order to get out of the danger zone before shot time.

The raft laying operation started approximately five hours before shot time; the flights were taken at levels of 1000' to 1500' in accordance with operating instructions.

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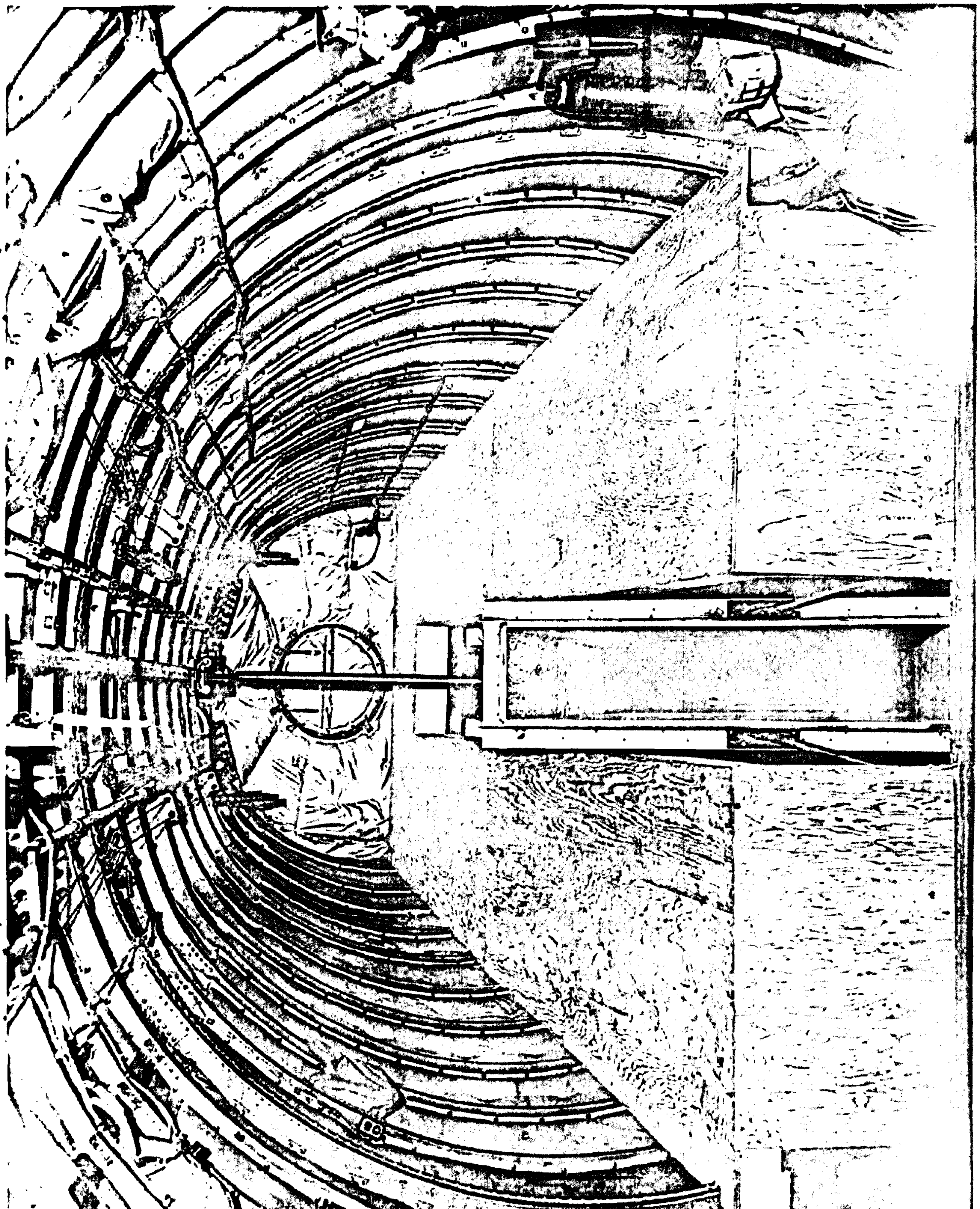

FIGURE VII

About 30% of the styrafoam and 10% of the plywood rafts. were to be im-

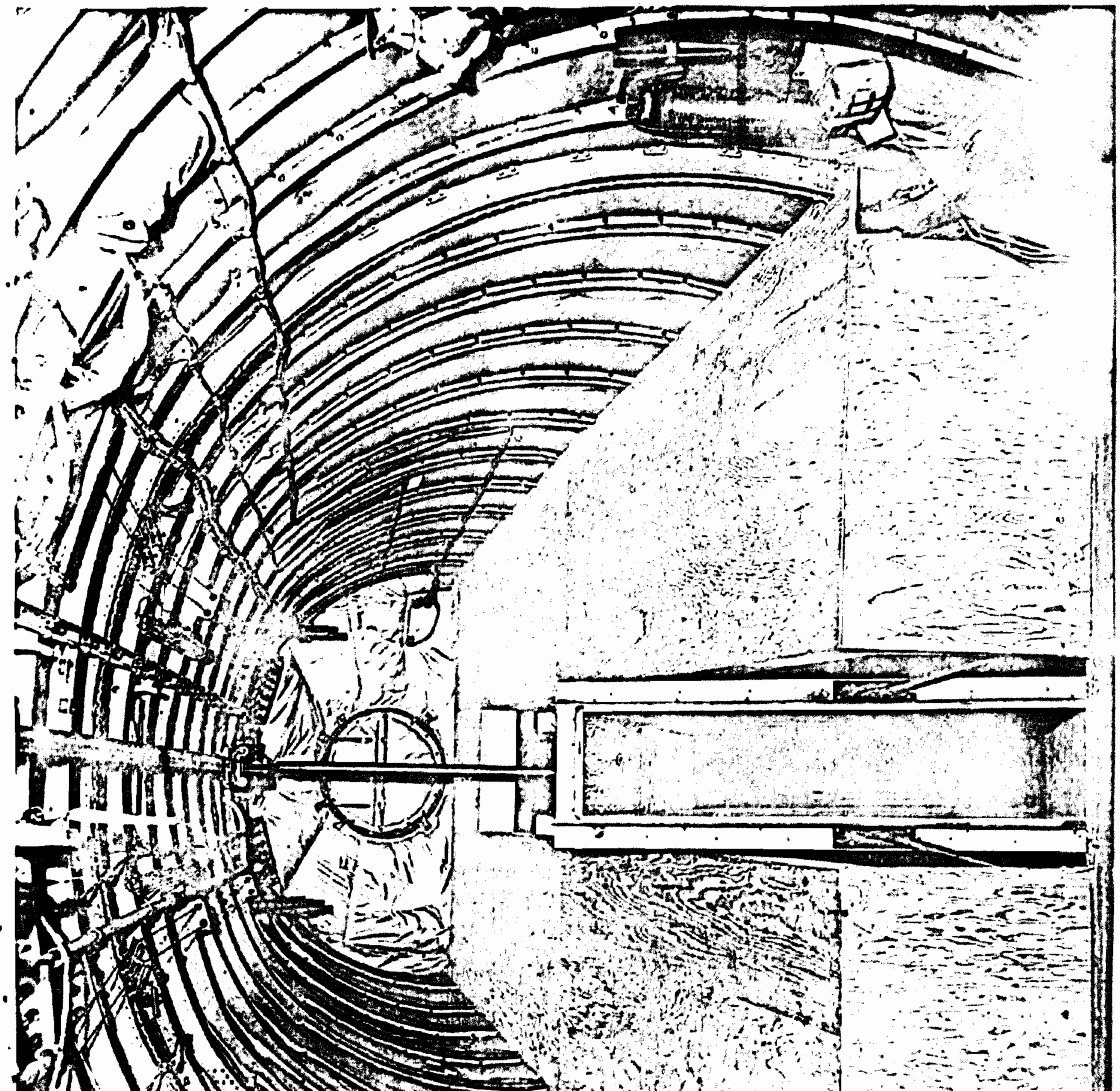

FIGURE VII

[redacted]

SURFACE TREATMENT AND IDENTIFICATION

About 50% of the styrafoam and 10% of the plywood rafts were to be impregnated with a low viscosity silicone oil which had been previously colored with "flaming red" dye. Each raft was numbered with painted figures 18" high in order to permit identification from the air.

RADIATION DETECTION EQUIPMENT

In the original thoughts on radiation detector needs, in particular, based on the evidence that at 100 miles from ground zero a gummed paper sample on board a ship yielded approximately 1 millicurie per sq. ft. of activity, the radiation detection system was designed to read a change of radiation flux 10% above a normal background of .01 mr/hr. This necessitated the use of a very large detector. It was expected that a 16" photomultiplier tube, DuMont type K-1258 in conjunction with a large liquid phosphor 16" diameter x 8" thick would suffice to give good statistical information. This detector had a counting rate change of about 5000 counts per second with a change of .01 mr/hr. Since it was expected that the activity level would rise by a factor of 10 or 20, the counting circuits had a capability of reading up to one million counts per second, Figure 18. This general circuitry was in the process of design for aerial reconnaissance to determine ore location under conditions where cosmic ray activity would be a significant portion of the counting background. This equipment was therefore designed to blank out information pulses above a predetermined energy level, which for convenience was set at 1.3 mev to allow the use of a Cobalt 60 source for setup.

The ratemeter system and high voltage supply were also adaptable to the use of smaller phosphors including 3" diameter x 2" thick sodium iodide and 1-1/8" diameter x 1-1/2" thick sodium phosphor. By reducing the phosphor size the system could be made useful by a reading up to 20 mr/hr.

In addition to the pulse type of system a highly sensitive aerial survey detector, the Scintair - was taken since no full knowledge of activity levels was available over open sea. The Scintair has 3" photomultiplier to which a 3" diameter x 2" high sodium iodide phosphor was coupled. This system feeds into an electrometer tube circuit, see Figure VIII. The scale is linear and reads to approximately two times the background of .01 mr/hr.

In addition, Scintameters (2) were included, Figure IX. These are supplied with a wide range logarithmic scale and can read from background levels of .005 mr/hr to 100 mr/hr.

SEARCH

Two P2V's were equipped with scintillation counter radiation detectors which fed linear scale pulse type ratemeters. These units actuated Esterline-Angus Recorders which presented the data in graphical form.

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(2) "Logarithmic D-C Ratemeters for Scintillation Counters" Nucleonics February 1954, Vol. 12, Pgs. 36-39.

[redacted]

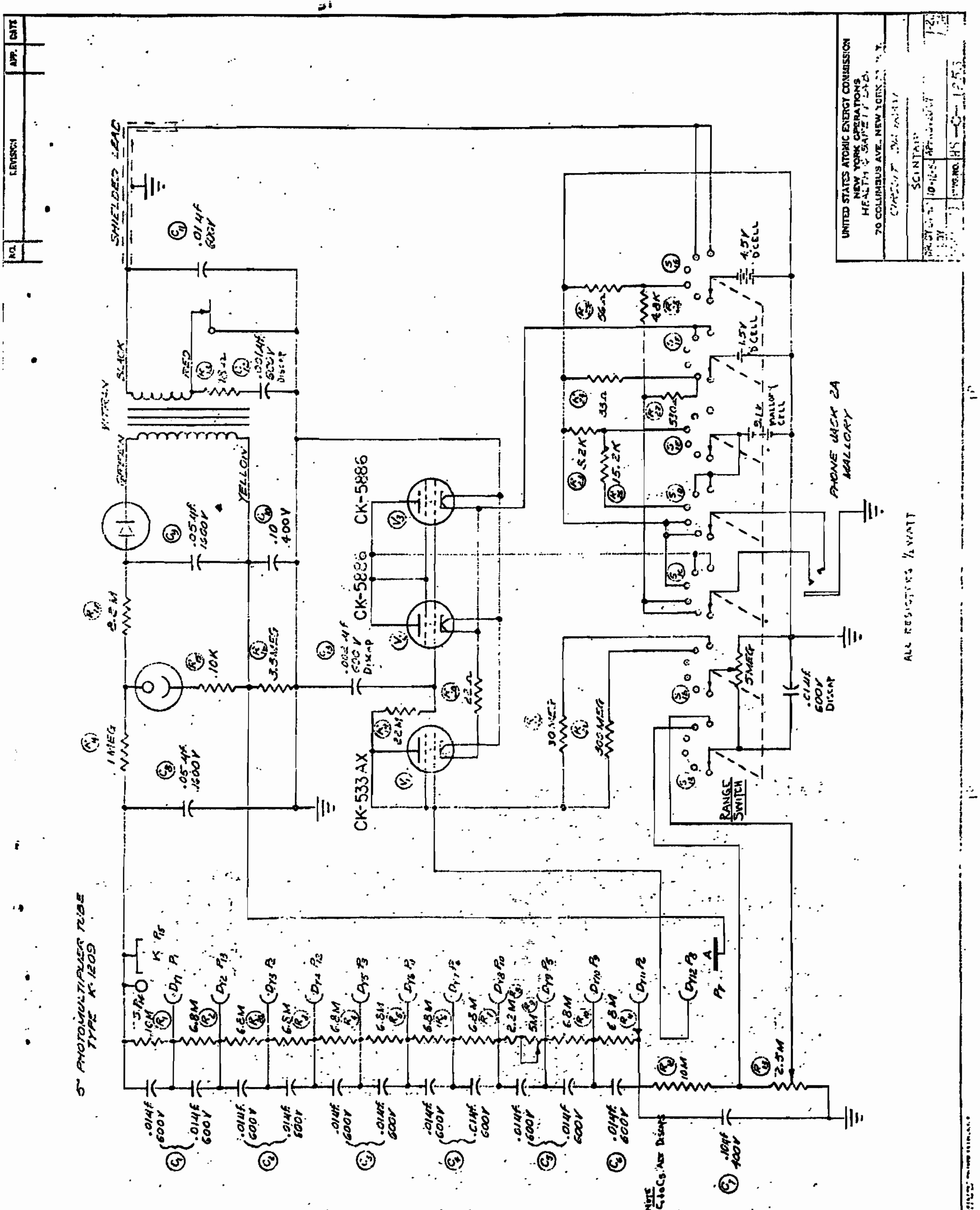
UNITED STATES ATOMIC ENERGY COMMISSION
NEW YORK OPERATIONS
70 COLUMBUS AVE., NEW YORK
SHIELDED LEAD
BLACK
RED
GREEN
YELLOW
CK-5886
CK-5886
CK-533AX
PHONE JACK 2A MALLORY
RANGE SWITCH
ALL RESISTORS 1/2 WATT
5" PHOTOMULTIPLIER TUBE TYPE K-1209

FIGURE VIII

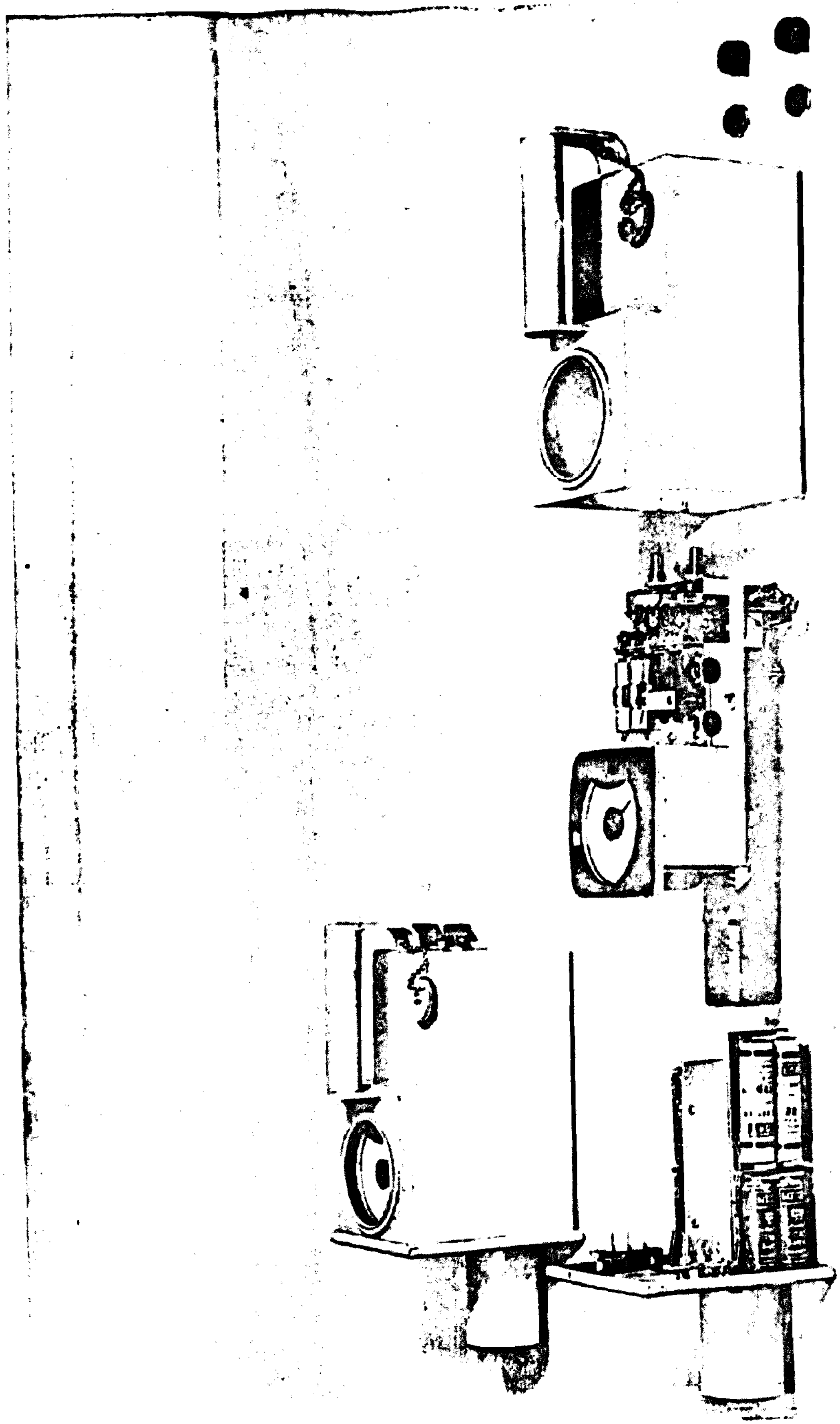

FIGURE IX

Because of stormy weather on YANKEE D+1 and the fact that observers had not previously viewed a raft from 200', no rafts were located during the first hour flight in either plane over the zone of interest. Later in flight, one plane located approximately seven rafts, the second one located one.

From the rafts located, however, the drift could be determined and radiation measurements taken. Throughout the flights it was noted that the apparent background was varying markedly and would rise and fall depending upon the position of the plane.

On D+3 a second search was instituted and resulted in relocation of one of the rafts that had been found on D+1; and the spotting of approximately 20 more rafts in the first two lines which contained approximately 100 rafts. Only one of the rafts could be identified by number; no radiation readings were possible because activity was washed off by wave action. The re-identified raft was one which had been painted with a material containing a solvent which dissolved the styrafoam. Most of the other 300 rafts were painted with an oil base enamel which seemed to have washed off.

No benefit was derived from the red coloration of the silicone, the uncoated rafts both styrafoam, and plywood were at least as visible as the red dyed ones.

Of two valid radiation readings taken, one indicated approximately 1 millicurie per sq. ft., the second 15 megacuries per sq. ft. It was evident that the second reading was taken in a zone that contained water in which some activity had been dissolved. The reading was not of raft activity but the entire ocean surface seen by the detector.

CONCLUSIONS

Although this program did not meet with success as a raft measuring activity, it is the author's opinion that any other program might be equally unsuccessful although with a large expenditure it would be possible to provide rafts with powerful radiosondes, to use rafts with large surface areas and to launch these units from a sufficiently large number of airplanes.

The inhibiting factors would probably rise from:

1. The size of the rafts would make solid construction almost impossible.

2. If a radiosonde with antenna erection mechanized plus other accessory equipment had to be launched large working crews are required or a pre-packed design is absolutely necessary.

3. The presence of some dissolved or suspended activity in the sea water surrounding the rafts would provide an infinite plane radiation source - with the raft, a small point source, within it. It might be practically impossible to read the raft activity with any precision.

[redacted]

4. Major improvements would have to be made on homing equipment in the military planes since these units are not designed for the relatively weak signals that a battery operated radiosonde could produce. These direction finders generally home on powerful shorebased commercial transmitters.

5. The ever present possibility that a complete array of rafts might be lost if the test was called off several hours before projected shot time since these rafts would have to be launched 4 or 6 hours prior to shot time to avoid drift out of the fallout pattern.

[redacted]

[redacted]

[redacted] [redacted]